NSW GOVERNMENT | sydney METRO

West

Westmead to The Bays and Sydney CBD

Environmental Impact Statement

Concept and Stage 1

Technical Paper 9
Hydrology and flooding

Sydney Metro West – Stage 1

Technical Paper 9: Hydrology and flooding

| Final

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Sydney Metro West – Stage 1 – Technical Paper 9: Hydrology and Flooding

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Executive Summary

Sydney Metro (as 'the proponent') is seeking approval for the Sydney Metro West Concept and for construction of the first stage (Stage 1). Planning approvals for Sydney Metro West are expected to be staged as follows:

- Stage 1 would involve the major civil construction works between Westmead and The Bays (further described in Chapter 9 (Stage 1 description) of this Environmental Impact Statement) and is being assessed concurrently with the Concept
- Future stage(s) would include the remaining major civil construction works from The Bays to Sydney CBD North, rail systems fit-out, station fit-out and aboveground building construction, and operation of the metro line.

Sydney Metro is seeking a specific declaration for Sydney Metro West to be declared as State significant infrastructure and critical State significant infrastructure under sections 5.12(4) and 5.13 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), respectively.

This technical paper has been prepared for Stage 1 to support the Environmental Impact Statement and to identify and assess the potential impacts of Stage 1 during construction, in relation to flooding. In doing so, this technical paper responds directly to the Secretary's Environmental Assessment Requirements.

This assessment has found that the majority of Stage 1 construction sites are at a low risk of flooding as the sites are generally located away from overland and mainstream flood areas and/or are at elevations above the effects of coastal inundation. The sites that are impacted by the 1% annual exceedance probability (AEP) flood event are only affected by minor, shallow overland flooding in the 1% AEP event. Some sites would also be affected by flooding in the probable maximum flood event.

Minimum flood protection levels have been estimated for each of the sites to appropriate design standards to protect construction phase features from flooding, including shafts and formations. Flood protection levels of 1% AEP flood level plus 0.5 metres freeboard or the probable maximum flood level, whichever is higher, have been adopted in order to prevent ingress of floodwaters into excavated voids or the tunnels underground. Additional freeboard allowance of up to 0.5 metres above the probable maximum flood level may need to be provided for the Parramatta metro station construction site if works coincide with, or follow, the redevelopment of the Camellia Town Centre.

Where required, mitigation measures and strategies have been identified for the construction sites to mitigate the potential impacts on flooding. This includes potential increases in flood levels, depths and flow velocities and scour potential. With mitigation, it is expected that the impact of Stage 1 on the flood-affectation to other properties, assets and infrastructure and flood emergency evacuation would be low. Resultant impacts to social and economic costs from flooding are also expected to be low. The potential cumulative flood impacts with other proposed development are expected to be generally low up to the 1% AEP flood event due to the low flood-affectation and flood impacts posed by Stage 1 and most of the other proposed developments. In cases where there are potential cumulative impacts, these are expected to be resulting from other proposed development(s).

The flood modelling completed for Stage 1 at the Clyde stabling and maintenance facility construction site found that Stage 1 would increase flood level up to 0.08 metres in and adjacent to Duck Creek and Duck River in the 5% and 1% AEP events. The increase affects several commercial and industrial properties outside of the site. These increased flood levels appear to be below the floor levels of existing buildings affected, based on ground levels and site observations. This would need to be confirmed with detailed survey. Opportunities to minimise increases would occur during detailed design and would be informed by floor level surveys of existing properties.

Modelling of climate change impacts on flooding has been undertaken for the setting of flood protection levels for the permanent structures that form part of the Clyde stabling and maintenance facility construction site. The flood protection levels at the construction site are based on the probable maximum flood level at the tunnel dive

crest location. The probable maximum flood level does not increase at this location as a result of sea level rise up to the year 2100, hence no additional provision is required in the flood protection level to allow for the impacts of climate change and sea level rise.

A review of floodplain risk management plans, developed and adopted by councils to manage flood risk, has been undertaken and no significant inconsistencies or conflicts between Stage 1 and the plans have been identified. One proposed mitigation option for Inner West Council in the vicinity of The Bays Station construction site may impact on Stage 1 if both the proposed option and Stage 1 are constructed at the same time. This option involves the duplication of existing trunk drainage culverts under the roadway adjacent to the site. This potential option is not a high priority in the floodplain risk management plan.

Glossary of terms and abbreviations

Term	Meaning
AEIs	Areas of environmental interest
afflux	Increase in flood level as a result of obstruction to flow
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. The following relationships between AEP and ARI applies to this study (ARR, 2019).

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very frequent	**12**			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.50
Frequent	**1**	**63.2**	1.58	1.00
	0.69	**50.00**	2	1.44
	0.5	39.35	2.54	2.00
	0.22	**20.00**	5	4.48
	0.2	18.13	5.52	5.00
Infrequent	0.11	**10.00**	10.00	9.49
	0.05	**5.00**	20	20.0
	0.02	**2.00**	50	50.0
	0.01	**1.00**	**100**	100
Rare	0.005	0.50	**200**	200
	0.002	0.20	**500**	500
	0.001	0.10	**1000**	1000
Extremely Rare	0.0005	0.05	**2000**	2000
	0.0002	0.02	5000	5000
			↓	
Extreme			PMP	

Term	Meaning
ARR	Australian Rainfall and Runoff. Guidelines prepared by the Institute of Engineers Australia for the estimation of design floods. Reference is made to the 1987 or the 2016 versions of ARR, as specified.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. Also refer to Average Exceedance Probability (AEP), which is the industry standard terminology for definition of design flood events.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
conveyance	The transport of flood water downstream.
DECC	Former NSW Government Department of Environment and Climate Change. Now the Department of Planning, Industry and Environment (Environment, Energy and Science).
development	Is defined in Part 4 of the EP&A Act In fill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use (e.g. The urban subdivision of an area previously used for rural purposes). New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area (e.g. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale). Redevelopment generally does not require either re-zoning or major extensions to urban services.
DIPNR	Former NSW Government Department of Infrastructure, Planning and Natural Resources. Now the Department of Planning Industry and Environment (DPIE).

Term	Meaning
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
exceedances per year (EY)	The number of times an event is likely to occur or be exceeded within any given year.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land /flood prone land	Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the probable maximum flood event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area)
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
floodplain risk management options	The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designated flood" or the “flood standard” used in earlier studies.

Term	Meaning
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.
flood readiness	Readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
hazard	A source of potential harm or situation with a potential to cause loss. In relation to this technical paper the hazard is flooding which has the potential to cause damage to the community.
hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at a particular location varies with time during a flood.

Term	Meaning
hydrology	The study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
IFD	Intensity Frequency Duration. Describes rainfall in terms of intensity (typically mm/hr), frequency (e.g. ARI) and duration of the storm.
LEP	Local Environmental Plan
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
LPI	Land and Property Information
m AHD	metres Australian Height Datum (AHD)
m/s	metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
modification measures	Measures that modify either the flood, the property or the response to flooding.
overland flow path	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.
probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The probable maximum flood defines the extent of flood prone land, that is, the floodplain.
probable maximum precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to probable maximum flood estimation.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this technical paper it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

Term	Meaning
runoff	The amount of rainfall which ends up as a streamflow, also known as rainfall excess.
scour	Erosion by mechanical action of water, typically of soil.
stage	Equivalent to water level (both measured with reference to a specified datum)
SEARs	Secretary's Environmental Assessment Requirements
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.

1. Introduction

1.1. Sydney Metro West

Sydney Metro West is a critical step in the delivery of Future Transport Strategy 2056. It would provide a fast, reliable and frequent rail service between Greater Parramatta and the Sydney CBD.

Sydney Metro (as 'the proponent') is seeking planning approvals as follows:

- Approval for the whole Sydney Metro West (at concept level) concurrent with Stage 1. Stage 1 involves the major civil construction works between Westmead and The Bays (and is the subject of this technical paper)
- Future stage(s) would include the remaining major civil construction works from The Bays to the Sydney CBD, rail systems fit-out, station fit-out and aboveground building construction, and operation of the metro line (future application(s)).

Sydney Metro is seeking a specific declaration for Sydney Metro West to be declared as State significant infrastructure and critical State significant infrastructure under sections 5.12(4) and 5.13 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), respectively.

1.1.1. Location

Sydney Metro West would mainly be underground in twin tunnels. Stage 1, which is subject of this assessment, extends from Westmead to The Bays (refer in Figure 1-1).

1.1.2. Overview of Stage 1

The Stage 1 would involve the major civil construction work for Sydney Metro West (Westmead to The Bays), including:

- Enabling works such as demolition, utility supply to construction sites, utility adjustments and modifications to the existing transport network
- Tunnel excavation including tunnel support activities
- Station excavation for new metro stations at Westmead, Parramatta, Sydney Olympic Park, North Strathfield, Burwood North, Five Dock and The Bays
- Shaft excavation for services facilities at Rosehill (within the Clyde stabling and maintenance facility construction site), Silverwater and between Five Dock Station and The Bays Station construction sites
- Civil work for the stabling and maintenance facility at Clyde including earthworks and structures for crossings of A'Becketts Creek and Duck Creek
- A concrete segment facility for use during construction located at the Clyde stabling and maintenance facility construction site
- Excavation of a tunnel dive structure and associated tunnels at Rosehill to support a connection between the Clyde stabling and maintenance facility and the mainline metro tunnels.

The Stage 1 is further described in Chapter 9 (Stage 1 description) of the Environmental Impact Statement.

The location of the services facility between Five Dock Station and The Bays Station is currently being investigated, and is not assessed within this technical paper. Further detail on the locational and design criteria that would be used as part of determining the preferred location is detailed in Chapter 9 (Stage 1 description) of the Environmental Impact Statement.

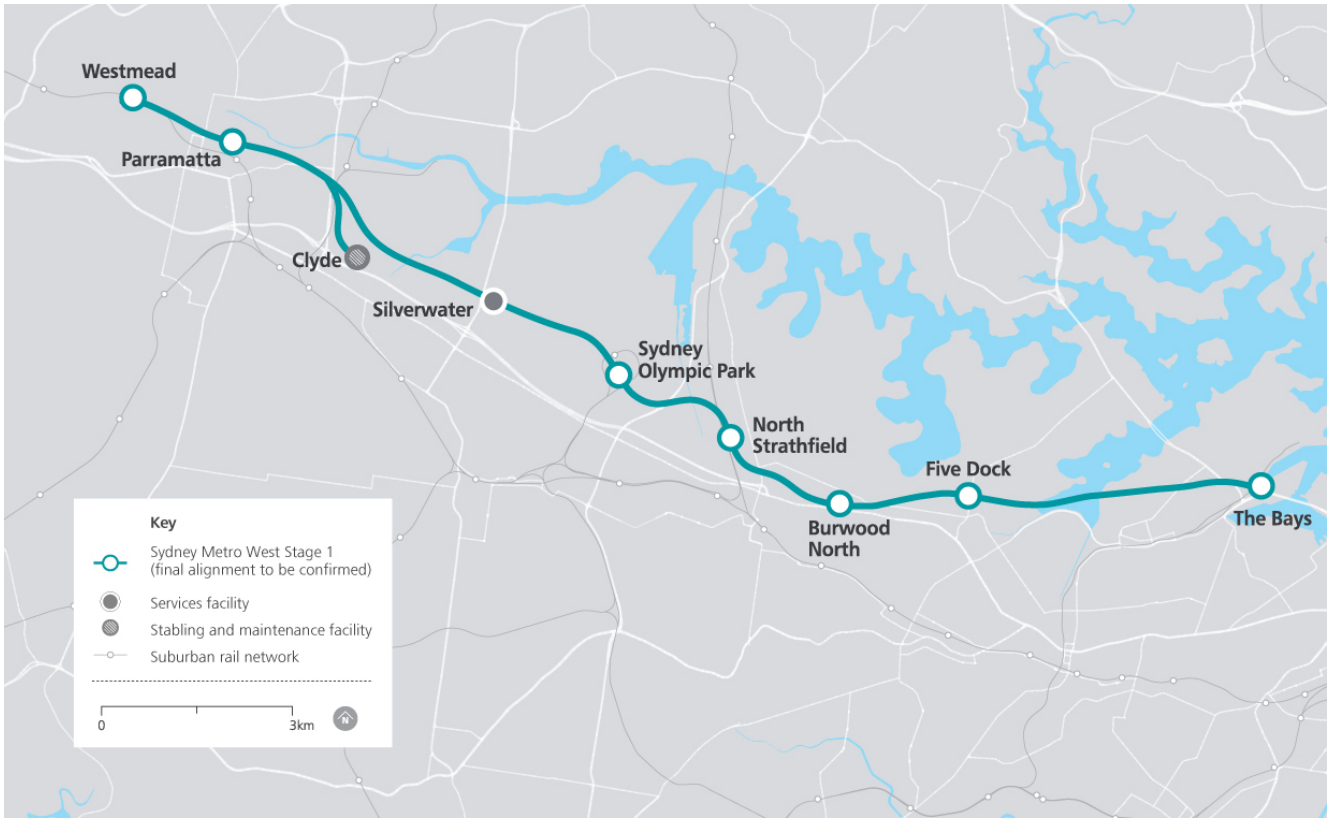

Figure 1-1: Sydney Metro West – Stage 1 overview

1.2. Purpose of this report

This technical paper is one of a number of technical documents that forms part of the Environmental Impact Statement for the project. The purpose of this technical paper is to identify and assess the potential impacts of Stage 1 in relation to hydrology and flooding. In doing so it responds directly to the Secretary's Environmental Assessment Requirements outlined in Section 1.3.

The objectives of this hydrology and flooding assessment are to:

- Characterise existing flooding behaviour and identify flood risks during construction
- Assess hydrology and flooding impacts which could occur during Stage 1
- Identify mitigation measures for Stage 1.

1.3. Secretary's Environmental Assessment Requirements

The Secretary's Environmental Assessment Requirements were issued for Stage 1 on 11 December 2019. The Secretary's Environmental Assessment Requirements relating to this assessment, and where these requirements are addressed in this report are outlined in Table 1-1.

In support of seeking the Secretary's Environmental Assessment Requirements, the Sydney Metro West Scoping Report – Westmead to The Bays and Sydney CBD (Sydney Metro, 2019) identified a number of investigations and further assessments. Where these requirements are addressed in this report are outlined in Table 1-2.

Table 1-1: Secretary's Environmental Assessment Requirements – Water – Hydrology and flooding

Secretary's Environmental Assessment Requirements*	Where addressed
5. Flood behaviour for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including:	This technical assessment provides a qualitative assessment of construction sites except for the stabling and maintenance facility. Refer to Section 3 and Section 4. Figures in Appendix A illustrate existing flood behaviour, where data is available. For climate change, refer to Section 4.2.3. Future climate change and its impacts on flooding behaviour are only relevant to the civil construction works associated with the stabling and maintenance facility construction site. The reminder of Stage 1 is expected to be completed before the onset of future climate change.
(a) potential flood affectation of other properties, assets and infrastructure;	Refer to Section 4.
(b) consistency (or inconsistency) with applicable Council floodplain risk management plans;	Refer to Section 4.6.
(c) compatibility with the flood hazard of the land; and	Refer to Section 4.4.
(d) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land.	Refer to Section 4.4

* Only part of this requirement is relevant to this technical paper. The full Secretary's Environmental Assessment Requirement for Water – Hydrology and flooding is provided in the Environmental Impact Statement.

Table 1-2: Further investigations and assessments – Hydrology and flooding

Proposed further assessment	Comment
The assessment of hydrology and flooding impacts will include:	
– Identification of any potential changes to flood levels, discharges, velocities, duration of flood inundation and flood hazards for the five per cent and one per cent Annual Exceedance Probability flood events, and probable maximum flood	Refer to Section 4, noting that information on the five per cent Annual Exceedance Probability flood event was not available for most Stage 1 sites.
– Identification of appropriate mitigation and management measures	Refer to Section 5.

1.4. Structure of this report

This report is structured according to the following sections:

- Section 1 – Introduction.
- Section 2 – Assessment methodology: Description of the assessment methodology including legislative background, design criteria, assessment scope and data sources.
- Section 3 – Existing environment: Description of the existing flooding behaviour in the vicinity of each construction site.
- Section 4 – Construction impacts: The assessment of the potential impacts of Stage 1 and risks to construction sites, as well as consideration of other relevant matters (floodplain risk management, impacts to emergency management etc).
- Section 5 – Mitigation and management measures.
- Section 6 – References.
- Appendix A – Flood mapping for Stage 1 construction sites: Flood extent (depth) and flood hazard mapping for 1% annual exceedance probability (AEP) and probable maximum flood (PMF) events, where available from existing studies.
- Appendix B – Summary of flood modelling and impact assessment for Clyde stabling and maintenance facility construction site (including permanent structures associated with Stage 1 for the Rosehill services facility and the Rosehill dive structure and tunnel portal).

2. Assessment methodology

The methodology for this hydrology and flooding technical paper is summarised below:

- Desktop review of publicly available flood study reports from local council(s) and other sources to characterise existing flooding conditions at all Stage 1 construction sites and the surrounding areas. Parameters considered include, where information is available:
    - The topography in the vicinity of the sites and presence of flow paths and watercourses, using aerial laser survey data
    - Flood depths and levels
    - Flood hazard
    - Flood hydraulic categories including floodway and flood storage
    - Flood planning area and flood planning level.
- Assessment of the potential impacts of Stage 1 on flooding that considers events up to the probable maximum flood, with a focus on:
- Assessment of potential increases in flood risk and flood affectation on adjacent properties and assets, and potential impacts to existing emergency management arrangements
- Land use compatibility with respect to flood hazard and floodway/flood storage areas
- Compatibility with relevant council floodplain risk management
- Assessment of potential morphologic (increased flow velocity and scour), environmental, social and economic impacts due to changed flood behaviour resulting from Stage 1.
- Where required, mitigation and management measures have been identified.

A qualitative assessment has been completed for the majority of Stage 1 and is based on interpretation of available flood study information for existing conditions and present day climate. This level of assessment is appropriate for the majority of construction sites given their general low level of flood exposure in addition to the low risk of significant flooding impacts due to Stage 1. Most of the sites are currently developed and Stage 1 works would replace existing structures with construction stage works which would have a similar influence on flooding behaviour to the existing case.

Quantitative assessment of flooding and flood impacts has been undertaken for the permanent structures and landform that would be constructed as part of Stage 1 at the Clyde stabling and maintenance facility construction site. This includes structures for the dive and tunnel portal as well as the services facility at Rosehill. This modelling has also taken into account climate change. Further information on the flood modelling is provided in Section 2.4 and Section 4.2.

The flooding assessment is based on the conceptual design of the construction sites as provided in the Environmental Impact Statement.

It is assumed that any current re-development of the catchment areas outside the construction sites would not increase the flood risk to the sites and that adequate controls would be provided by any future development to mitigate potential flood impacts. Any potential impacts from current re-development may not be accounted for.

This assessment is based on the information and outcomes from available flooding studies only at the time of the assessment. A number of studies are ongoing and may result in new or updated information, which may affect further assessment outcomes of this assessment.

2.1. Relevant legislation, guidelines and policies

The assessment has been undertaken generally in accordance with the following key guidelines and design references as applicable:

- *NSW Floodplain Development Manual* (NSW Government, 2005)
- Australian Rainfall and Runoff (ARR).

The assessment of potential flooding impacts of Stage 1 on existing flood regimes has been conducted in accordance with the requirements of the *Floodplain Development Manual* (NSW Government, 2005), which incorporates the NSW Government's *Flood Prone Land Policy*. The key objectives of this policy are to identify potential hazards and risks, reduce the impact of flooding and flood liability on owners and occupiers of flood prone property, and to reduce public and private losses resulting from floods. This policy also recognises the benefits of the use, occupation and development of flood prone land.

Most existing flood studies reviewed in this assessment are based on the design rainfall data provided in *Australian Rainfall and Runoff 1987*. A limited number of the existing studies are more recent and are based on *Australian Rainfall and Runoff 2019* design rainfall data, which typically estimates 20 – 30 per cent lower design rainfalls across the Sydney Region compared to *Australian Rainfall and Runoff 1987*. Hence, flood affectation of the Stage 1 construction sites would be lower with *Australian Rainfall and Runoff 2019*. Consideration of flood affectation and flood impacts during detailed construction planning should consider *Australian Rainfall and Runoff 2019*.

2.2. Design criteria and performance outcomes

The key design criteria and standards relevant to Stage 1, or as set as performance outcomes set for the Concept (refer to Chapter 8 (Concept environmental assessment) of the Environmental Impact Statement) are:

- The Clyde stabling and maintenance facility landform would be designed to be protected from the probable maximum flood
- The dive structure and tunnel portal at Rosehill would be designed to be protected from the probable maximum flood event
- The design for permanent infrastructure completed as part of Stage 1 would incorporate allowance for climate change consistent with Representative Concentration Pathways (RCP) 8.5. The RCP8.5. refers to the upper range projection of greenhouse gas concentrations in the atmosphere as adopted by the Intergovernmental Panel on Climate Change (IPCC) in 2014 for the assessment of climate change impacts
- Excavations for stations and service facility shafts would be protected from floodwater inflows. Where feasible the protection level would be above the probable maximum flood or at least 0.5 metres above the 1% AEP flood level, whichever is the greater. Where it is not feasible or reasonable to meet the criteria, additional controls would be required to manage any potential inflows
- Additional flood protection allowances would be required where construction sites are subject to coastal inundation
- Minimise increases in flood levels due to temporary and permanent infrastructure completed by Stage 1 during flood events up to an including the one per cent AEP event
- No additional private properties would be affected by flooding up to and including the 1% AEP flood event due to permanent infrastructure completed by Stage 1
- Dedicated evacuation routes would not be adversely impacted in flood events up to and including the probable maximum flood.

2.3. Sources of data

A number of previous flooding studies have been undertaken for catchment areas at the majority of the construction sites and which are publicly available. These studies have been identified and reviewed as part of this assessment. Construction sites where flood studies have not been undertaken have been reviewed and are typically considered to have low or nil flood-affectation based on their location in the catchment areas. The exception is the Silverwater services facility construction site where previous flood studies do not assess flooding on the site but review of topographic data indicates potential exposure to overland flooding. This is discussed further in Section 3.3.4.

Detailed flood modelling has been undertaken as a part of this study for Clyde stabling and maintenance facility (including the tunnel dive) to adequately assess flood behaviour and impacts at and around this construction site. The outcomes from this modelling have been considered in this assessment. Refer to Appendix B for documentation of this detailed flood modelling.

Table 2-1 summarises the available studies at each site and outlines the data types required to address aspects of this assessment which were not available from these studies or which are yet to be received for this assessment.

Table 2-1: Sources of available data for hydrology and flooding assessment

Construction site	Local government area	Data sources
Westmead metro station	Parramatta	Parramatta Light Rail Flooding Technical Paper (Arup, 2017) The site is in the vicinity of, but just outside, the Parramatta Light Rail flood modelling area.
Parramatta metro station	Parramatta	Parramatta Light Rail Flooding Technical Paper (Arup, 2017)
Clyde stabling and maintenance facility	Parramatta	Parramatta Light Rail Flooding Technical Paper (Arup, 2017) *Duck River and Duck Creek Flood Study Review* (*WMAwater, 2015)* *Stage 2 Report – Camellia Precinct Drainage and Flooding Study (Cardno, 2015a)* Note: flooding conditions not adequately assessed by previous studies.
Silverwater services facility	Parramatta	*Duck River and Duck Creek Flood Study Review* (*WMAwater, 2015)* Note: flooding conditions not adequately assessed by previous studies.
Sydney Olympic Park metro station	Parramatta	N/A. No previous flood study.
North Strathfield metro station	Canada Bay	*Concord West Precinct Master Plan Flood Study* (Jacobs, 2015)
Burwood North Station	Burwood/Canada Bay	WestConnex M4 East EIS Appendix Q - Surface Water: Flooding and Drainage (Lyall & Associates, 2015) *Exile Bay, St Luke's and William Street Flood Study* (WMAwater, 2017)

Construction site	Local government area	Data sources
Five Dock Station	Canada Bay	N/A. No previous flood study.
The Bays Station	Inner West	Leichhardt Floodplain Risk Management Study and Plan (Cardno, 2017) *Leichhardt Flood Study* (Cardno, 2015b)

2.4. Quantitative assessment of the Clyde stabling and maintenance facility

Detailed hydraulic modelling was undertaken to define existing flooding conditions at and in the area surrounding the Clyde stabling and maintenance facility construction site, and flooding impacts as a result of civil construction works that form part of Stage 1. The spatial extent of modelling in the previous flood studies was not sufficient to accurately assess flooding at the construction site and in the broader floodplain.

Additionally, the potential for substantial impacts resulting from the civil works for the stabling and maintenance facility and other permanent structures at this location required quantitative analysis of construction phase and final state flooding behaviour at and around the site. The model assumptions and development is discussed in Appendix B and a summary of key parameters provided in Table 2-2.

Table 2-2: Key parameters for the Clyde stabling and maintenance facility construction site flood model

Model parameter	Application
Model	TUFLOW one-dimensional/two-dimensional hydraulic model. Two metre grid for 5% and 1% AEP events. Four metre grid for the probable maximum flood event. The model extends from Harris Street on A'Becketts Creek and upstream of the T1 Western Line on Duck River and Duck Creek down to the Parramatta River, and along the Parramatta River from James Ruse Drive downstream to Whitton Bride (Ryde Road).
Topographic data	LiDAR (NSW Land and Property Information in 2013). Bathymetric survey data of tidal watercourses (NSW Maritime, early to mid 2000's. Other channel geometry data for non-tidal watercourses extracted from existing flood models, and is assumed to be based on survey and design data for constructed channel sections.
Hydrological inputs	Inflows into Parramatta River, Duck Creek, Duck River and A'Becketts C/reek were obtained from the reference flood study models and are based on Australian Rainfall and Runoff 1987.

Model parameter	Application
	Inflows into the Parramatta River from the Upper Parramatta River Catchment are based on "Draft 8" scenario hydrology, which are the design flows adopted by City of Parramatta. Additional hydrologic modelling was undertaken for minor local catchment using the XP-RAFTS hydrologic model, based on Australian Rainfall and Runoff 1987.
Building footprints	Modelled as blocked obstructions.
Events simulated	5% and 1% AEP events and probable maximum flood event.
Climate change scenario	The relevant aspect of climate change impacts on Stage 1 are the potential increase in the flood protection level at the Clyde stabling and maintenance facility construction site, which is dictated by the probable maximum flood. Hence, a climate change scenario relating to the year 2100 was assessed for the probable maximum flood combined with sea level rise. The probable maximum flood event rainfall intensity does not increase with climate change. A 0.9 metre sea level rise was assumed.

2.5. Flood hazard definition in the existing flood studies

The method for defining flood hazard varies between the different flood studies reviewed for each site. These flood hazard definitions are described below.

Flood hazard mapping, where the flood hazard is rated thematically based on the flooding depth and velocity at any one time during a flood event, has traditionally been undertaken based on the definition in the *Floodplain Development Manual* (NSW Government, 2005) and shown on Figure 2-1. The *Floodplain Development Manual* definition of high (and low) flood hazard conditions are generalised and do not differentiate between the susceptibility of different members of the community and of different types of assets and property.

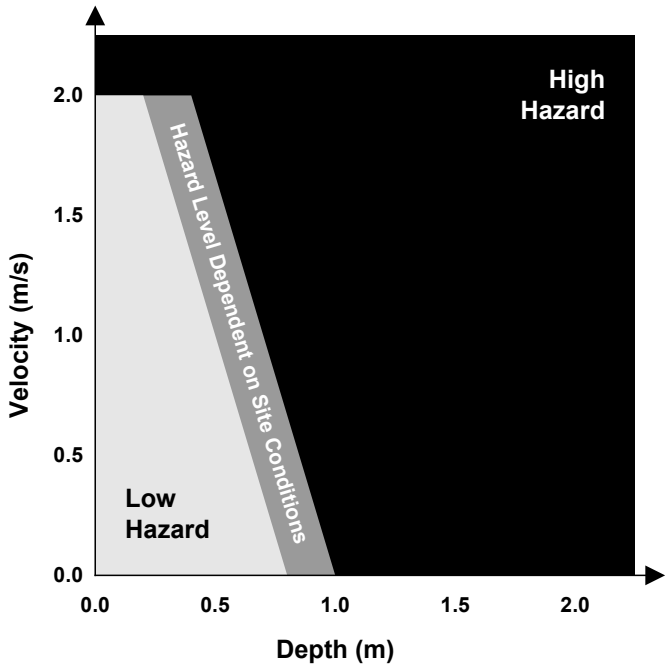

Figure 2-1 *Floodplain Development Manual* flood hazard category diagram (from Figure L2 in *NSW Floodplain Development Manual*)

Recent research has been undertaken into the hazard that flooding poses and the vulnerability of the public and assets when interacting with floodwaters. A combined flood hazard classification based on this research is presented in *Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017a) and *Guideline 7-3 Flood Hazard* (AIDR, 2017b), and is illustrated in Figure 2-2. This recent flood hazard method has been adopted in *Book 6: Flood Hydraulics of the Australian Rainfall and Runoff 2019* guidelines. The flood hazard categories according to the Australian Rainfall and Runoff 2019 definition are:

- H1 – Generally safe for people, vehicles and buildings
- H2 – Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles. Buildings require special engineering design and construction, and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

The flood hazard classification is more discrete and provides guidance on flood hazard thresholds to different members of the community (e.g. children and elderly) and different assets (small versus larger vehicles, standard versus specialised engineered buildings). The *Australian Rainfall and Runoff 2019* flood hazard definition potentially provides a more suitable guideline for assessing flood hazard on the floodplain from an emergency management perspective.

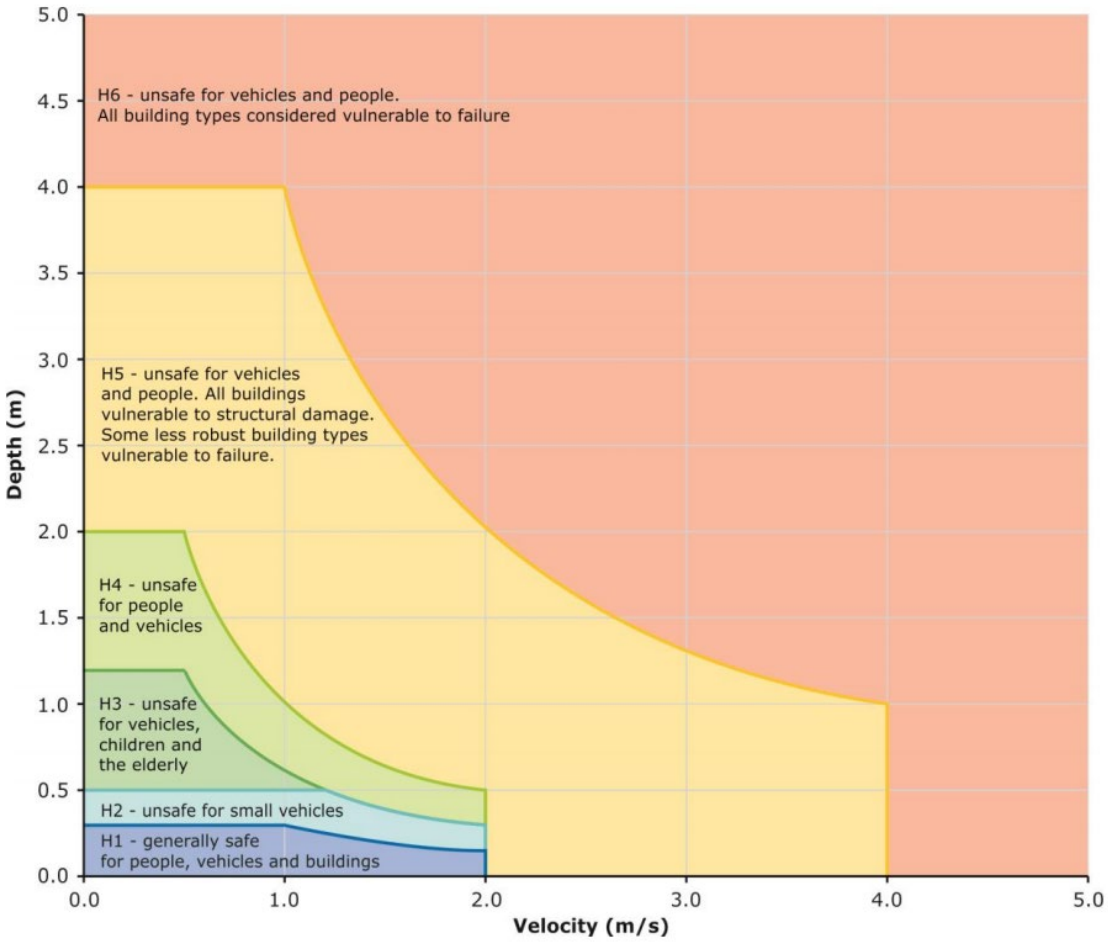

Figure 2-2 General flood hazard vulnerability curves, ARR 2019 categorisation

Most previous flood studies adopted the *Floodplain Development Manual* categorisation for defining flood hazard. More recent studies are increasingly adopting the *Australian Rainfall and Runoff 2019* categorisation method to reflect the refined knowledge on flooding conditions. In general, the *Australian Rainfall and Runoff 2019* H3 category and higher categories, roughly correspond with the high and transitional hazard categories in the *Floodplain Development Manual* method, with the *Australian Rainfall and Runoff 2019* method being slightly more conservative (lower depths and velocities may correspond to a high rating). To provide a consistent and simplified commentary on flood hazard in this technical paper, the assessment discussion relates to a "low" and "high" flood hazard rating consistent with *Australian Rainfall and Runoff 2019* H3 and higher category, and Floodplain Development Manual transitional and high category, being referred to as "high" hazard areas. The remaining area within the flood extent of the flood event being described is referred to as "low" hazard.

3. Existing Environment

The information presented below is based on a review of publicly available information including reports, studies, topographic data and aerial and site imagery.

There are four causes of flooding:

- Intense rainfall: local flooding may be caused by intense rainfall falling directly onto sites or adjacent to sites during storm events and which are not adequately managed by the provided drainage systems. This may cause nuisance flooding and disruption due to localised ponding of water and runoff within sites. This type of issue is broadly referred to as "drainage issues" in this assessment
- Overland flooding: occurs when local catchment runoff exceeds the capacity of existing drainage systems, with excess flows being conveyed on surface flow paths and ponding in low points. Development which is present in or adjacent to these flow paths and low points may be impacted by floodwaters. In this assessment, overland flooding has been broadly characterised as being "minor" in nature (expected shallow depths and/or relatively low velocity) or "major" (high depths and/or high velocity, typically in main flow paths and which may be classified as high hazard). Overland flooding is typically caused by short duration, intense rainfall resulting in rapid rise in flood flows with little or no warning time
- Mainstream flooding: occurs due to floodwaters in rivers, creeks and canals rising out of these watercourses and inundating the broader floodplain above bank level. Relevant watercourses include the Parramatta River in addition to tributary natural creeks and modified channels such as Duck River, Duck Creek, Powells Creek and St Luke's Park Canal. Mainstream flooding may be caused by prolonged heavy rainfall providing some warning time for rising floodwaters particularly for the large catchment of the Parramatta River. Although of short duration, intense rainfall storms over tributary catchments may result in flash flooding in some of the tributary channels such as Powells Creek and Duck River, with short warning times
- Coastal inundation: generally results from elevated ocean levels caused by storm surge due to low pressure weather systems and/or highest astronomical tides (i.e. "king tides"). These two mechanisms are independent of each other but may coincide and reinforce each other during a coastal inundation event. The elevated ocean levels affect the Parramatta River and its tributaries and adjoining low-lying areas. Coastal inundation events can also coincide with catchment and mainstream flooding, exacerbating its impacts by raising flood levels in and around the waterways.

Table 3-1 summarises causes of flooding affecting each construction site, which are discussed further in this section.

Table 3-1: Summary of existing flooding conditions at proposed construction sites

Construction site	Local government area	Cause of flooding		
		Coastal	Mainstream	Overland
Westmead metro station	Parramatta	-	-	No (local drainage only)
Parramatta metro station	Parramatta	-	Yes	Yes (minor)
Clyde stabling and maintenance facility	Parramatta	-	Yes	Yes (minor)
Silverwater services facility	Parramatta	-	Yes	Yes (major)

Construction site	Local government area	Cause of flooding		
		Coastal	Mainstream	Overland
Sydney Olympic Park metro station	Parramatta	-	-	No (local drainage only)
North Strathfield metro station	Canada Bay	-	-	Yes (minor to major)
Burwood North Station	Burwood/Canada Bay	-	-	Yes (minor)
Five Dock Station	Canada Bay	-	-	Yes (minor)
The Bays Station	Inner West	Yes	-	Yes (major)

3.1. Topography and drainage

The topography across the alignment (from Westmead to The Bays) is undulating at elevations typically less than 20 metres AHD with no dramatic inclines encountered. The terrain at individual construction sites are variable from a hydrologic perspective, with some locations situated on low-lying floodplain areas with others situated on hillsides and ridgetops. The terrain at and surrounding each construction site largely determines the flooding potential and risk. Topography and drainage conditions are summarised for each construction site in Table 3-2. Further detail is provided in Section 3.3.

Table 3-2: Topography and drainage across each construction site

Construction site	Topography and drainage
Westmead metro station	• The construction site is located on a hill with Hawkesbury Road to the west acting as a ridge with the land sloping, to the south towards Westmead Public School and east towards Domain Creek, which then flows northwards to the Parramatta River • The existing rail line is in a cutting to the north of the construction site • The elevation of the construction site is around 32 – 37 metres Australian Height Datum (AHD) • No natural overland flow paths affect the construction site. The construction site is near the top of a stormwater drainage line which flows northwards to Parramatta River.

Construction site	Topography and drainage
Parramatta metro station	• Largely flat area with slight northerly slope towards Parramatta River • The elevation of the construction site is around 9 – 10 metres AHD. The construction site is elevated compared to the immediate surrounding area • The construction site is located within the Parramatta River floodplain • Stormwater drainage flows to the north of the site, discharging to the Parramatta River.
Clyde stabling and maintenance facility	• Generally flat to undulating terrain. Highly modified ground surface from previous land use particularly on the Sydney Speedway located on NSW Government owned land • The construction site is located on the Duck Creek/A'Becketts Creek floodplain • Elevations on the Clyde stabling and maintenance facility construction site are generally three to six metres AHD with some raised mounds up to 10 metres AHD on the Sydney Speedway site. The tunnel dive structure site to the north has elevations that range from five to 15 metres AHD • The construction site is split into the northern and southern portion by Duck Creek and A'Becketts Creek. Drainage on the construction site is generally towards these creeks although undulations on the current site surface would cause ponding of local runoff and reduce free surface drainage of flows to the creeks. The existing landform on the Sydney Speedway site forms a significant basin which would cause ponding of runoff • No natural overland flow paths affect the construction site. Existing stormwater drainage arrangements are unknown.
Silverwater services facility	• Gently sloping site at an elevation of five to 5.3 metres AHD, with land sloping to the north-west towards Duck River. • The construction site is located adjacent to an overland flow path in Derby Street with a catchment of about 29 hectares and which drains in a westerly direction. It is also within the broader Parramatta River floodplain but would only be affected by mainstream flooding in extreme events. • Existing stormwater drainage arrangements are unknown but are assumed to be located in Derby Street and Silverwater Road and drain to the north-west to Duck River.
Sydney Olympic Park metro station	• The construction site is located on relatively high ground with land generally sloping away from the site in each direction. The construction site has an elevation of around 16 – 25 metres AHD • Some localised drainage low points are present within the construction site. The existing stormwater drainage arrangements are unknown • No natural overland flow paths affect the construction site. The construction site is some distance away from the closest waterways which include Powells Creek, Haslams Creek and Homebush Bay.

Construction site	Topography and drainage
North Strathfield metro station	• There are two construction sites on Queen Street, located on relatively high ground. The elevation of the construction site is around 14 – 20 metres AHD • The natural catchment boundary is 200 metres to east, with the land sloping towards Powells Creek to the west. The Main Northern Railway and Queen Street include features such as kerbs and retaining walls which may act as obstructions to flow and contribute to overland flooding • Stormwater drainage pipelines cross the Railway and discharge to Powells Creek. There are also drainage channels alongside the railway corridor which intercept surface flows, including overland flows, and discharge via pipe drainage to Powells Creek.
Burwood North Station	• There are two construction sites at this location, a northern and a southern site, separated by Parramatta Road. • The northern construction site has an elevation of around 6.5 to 17 metres AHD. The southern construction site has an elevation of around 11.5 to 14 metres AHD. There is an easterly to south-easterly slope in topography toward Concord Oval. • The construction sites are located adjacent to a major overland flow path and St Luke's Park Canal but would not be affected by flooding except in extreme events. • Existing stormwater drainage flows eastward along Parramatta Road and discharges to St Luke's Park Canal.
Five Dock Station	• There are two construction sites at this location, an eastern and a western site, on either side of Great North Road. • The construction sites are located near the top of a hill and ridge with land sloping to the north to Hen and Chicken Bay. The construction sites have an elevation of around 16.5 to 20 metres AHD. • No natural overland flow paths affect the construction sites. Existing stormwater drainage drains to north and south away from the sites.
The Bays Station	• The construction site is situated on a low-lying former dockland site. There is a section of lower land immediately to the west (former White Bay Power Station site) which forms part of a major overland flow path that drains an area stretching north-west towards Rozelle. • The construction site is generally flat land with little to no slope around White Bay. The construction site has an elevation typically around three to four metres AHD with some low-lying sections along White Bay (one metre AHD) and a small section of higher land associated with the Victoria Road embankment in the south-east of the site. • Existing drainage arrangements not fully known but significant trunk drainage channel/culverts and floodways are visible to the north of the construction site, which are presumed to run under Robert Street and partly under the construction site before discharging to White Bay to the north-east of the site. Drainage arrangements on the former White Bay Power Station site are unknown and forms a trapped drainage point.

3.2. Land use

Land use in and around the construction sites is urbanised. Catchment areas draining to flow paths and watercourses in the vicinity of the construction sites are a mixture of low, medium and high density residential, commercial and industrial, with some parklands and open spaces. Also included in the catchment areas are several main rail and road transport corridors (e.g. M4 Motorway).

The construction sites themselves are located within residential, commercial and industrial areas. The Bays Station construction site is in an industrial and port land use area which is proposed for redevelopment. Further details at each site are provided in Section 3.3.

3.3. Existing flood conditions

The pre-development flooding conditions at and surrounding each construction site is described in this section. The assessment focusses on the 1% AEP flood event and probable maximum flood. As the sites have low or nil flood-affectation in the 1% AEP flood event, this implies similarly low or nil flood-affectation in smaller and more frequent flood events. The 1% AEP flood event and probable maximum flood are also the key events for flood planning and flood protection aspects.

The discussion of flooding behaviour is in relation to the defined construction footprint for each site and its surroundings.

3.3.1. Westmead metro station construction site

The Westmead metro station construction site is situated in the upper section of the Domain Creek sub-catchment of the Parramatta River catchment. The construction site is near the top of a hill at elevations of 32 – 37 metres AHD.

The Westmead metro station construction site is bound by the existing rail corridor, Hawkesbury Road, Bailey Street and Hassall Street, and is currently comprised mainly of low-density residential properties and several small commercial properties. The land uses surrounding the construction site is mainly low and medium density residential properties and some commercial properties. Westmead Hospital is located to the north of the site and the University of Western Sydney campus and a high school are located to the north-west of the site. A primary school is located just to the south-west of the site.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The construction site and immediate surrounds are outside of flood prone areas as identified by the existing flooding studies.

Being on a hill, the site and immediate surrounds are located away from main overland flow paths and watercourses and are outside of previous overland flood study extents, hence are not considered to be affected by overland flow. Available flood study mapping indicates the site and immediate surrounds are outside of the 1% AEP flood event and probable maximum flood extents and any flood hazard or floodway/flood storage area. Local runoff and drainage is expected to be contained within kerb and guttering in the adjacent roadways.

3.3.2. Parramatta metro station construction site

The Parramatta metro station construction site is located within the Parramatta CBD at elevation of nine to ten metres AHD on flat terrain. The construction site currently comprises a mix of commercial and retail properties and a multi-storey car park, and is bound by George Street, Church Street, Smith Street and Macquarie Street. Horwood Place runs through the construction site and may act as a flood flow path through the existing site in rare flood events. Land uses in the surrounding area are mainly high density commercial and residential.

The site is located within the Parramatta River floodplain, about 300 metres to the south of the river just downstream of the Charles Street weir. The site and surrounding area is subject to mainstream flooding from the Parramatta River and the upstream catchment area of about 110 square kilometres. While also subject to minor overland flooding, the main flooding constraint on the construction site and the surrounding area is related to mainstream flooding.

The peak probable maximum flood level is about 11.5 to 12.5 metres AHD, with the probable maximum flood depth adjacent to the site reaching up to two metres. Peak 1% AEP flood level is about nine to 10.7 metres AHD, with depths of up to 0.35 metres adjacent to the construction site. Maximum depths on the site are about 0.15 metres in the 1% AEP event and about one metre in the probable maximum flood.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The construction site and immediate surrounds are outside of high flood hazard areas in the 1% AEP flood event. Hydraulic categories mapping is not available for the site but given the terrain and flood depths the site is expected to be outside floodway and flood storage areas in the 1% AEP event.

3.3.3. Clyde stabling and maintenance and facility construction site

The Clyde stabling and maintenance facility construction site is located on and adjacent to the confluence of Duck Creek and A'Becketts Creek, and also just upstream of the Duck Creek and Duck River confluence. Elevations on the Clyde stabling and maintenance facility construction site are generally three to six metres AHD with some raised mounds up to 10 metres AHD on the Sydney Speedway site. Running north to the location where the dive structure and tunnel portal would be located, the elevations range from five to 15 metres AHD. The construction site is bounded by the M4 Motorway to the south, James Ruse Drive to the west and Unwin Street to the north. The eastern side of the construction site is bounded by Duck Creek, which turns to the west and then runs through the site, and Shirley Street.

Flooding on the construction site is caused by a combination of flood flows in A'Becketts Creek, Duck Creek and Duck River, both within the channels and flows on the floodplain which break out of the watercourse channels at various locations. During large to extreme flooding events, floodwaters in the Parramatta River may influence flooding in these tributary watercourses and may also directly contribute to flooding due to backwater.

Minor overland flows in James Ruse Drive may affect the northern extent of the construction site (where the dive structure and tunnel portal would be located), although these are likely to be only shallow in depth. Due to the size of the construction site, direct rainfall and runoff onto the site has the potential to cause flooding issues.

Within the construction site, the 1% AEP flood level in Duck Creek and A'Becketts Creek ranges from 4.1 to 5.3 metres AHD and up to 5.1 metres AHD respectively. The 1% AEP flood level is about seven metres AHD at the northern end of the site, in James Ruse Drive at Eleanor Street. Elsewhere, flooding on the construction site in the 1% AEP event occurs in low-lying areas to depths of 2.4 metres. About one quarter of the construction site is flood-affected in the 1% AEP event.

In the probable maximum flood, the flood levels adjacent to Duck Creek and A'Becketts Creek within the construction site ranges from 5.8 to 6.6 metres AHD, and about 7.1 metres AHD at the northern end of the site, in James Ruse Drive at Eleanor Street. Shallow overland flows occur at higher elevations within the northern areas of the construction site. The majority of the construction site is inundated in the probable maximum flood, with maximum depths of four metres in existing low points.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The construction site and immediate surrounds contains areas of high flood hazard areas in the 1% AEP flood event, within the watercourses and on low-lying sections of the floodplain. Most of the site is not flood-affected in the 1% AEP event. Hydraulic categories mapping is not available for the site but given the terrain and flood behaviour the site is expected to be mostly outside main floodway and flood storage areas in the 1% AEP event.

Existing roads in the vicinity of the construction site are prone to flooding. Key emergency access and evacuation routes include Parramatta Road, James Ruse Drive, which are affected to flood depths of up to 0.5 metres in the 5% AEP event, and the M4 Motorway, which is on a raised viaduct in the vicinity of the construction site and is not flood-affected. An existing B-double route, consisting of Unwin Street, Kay Street and Wentworth Street, is affected by flooding from Duck Creek and A'Becketts Creek in events more frequent than the 5% AEP event.

3.3.4. Silverwater services facility construction site

The Silverwater services facility construction site is located within the Duck River catchment. The construction site is located on the corner of Derby Street and Silverwater Road and is gently sloping with an elevation of five to 5.3 metres AHD, with land sloping to the north-west towards Duck River. The existing site is currently vacant, and was previously occupied by industrial premises. It is bounded on its eastern and southern sides by other industrial properties.

The construction site is located adjacent to an overland flow path in Derby Street with a catchment that fans out to the east through to south. Floodwaters would flow in a westerly direction down Derby Street to Silverwater Road, where it would pond and then cross the road and flow onwards to drain to Duck River. There is also a major overland flow path situated to the west of Silverwater Road which flows in a north-easterly direction.

The construction site is expected to be affected by major overland flows in Derby Street and Silverwater Road. The overland flow catchment is about 29 hectares in area and the site is immediately adjacent to this catchment outlet. Substantial overland flows are expected in Derby Street in the 1% AEP flood event, and potentially in more frequent events. Overland flooding in Derby Street and Silverwater Road at this location has not been assessed in the existing flood studies and hence flood depths, hazard and other flood behaviour in Derby Street has not been quantified.

Flooding in the overland flow path to the west of Silverwater Road is caused by local catchment flow in addition to backwater flooding from Duck River and Parramatta River. In the 1% AEP event the flood level is four metres AHD and does not affect the Silverwater services facility construction site. In the probable maximum flood, the flood level is 5.7 metres AHD and affects the construction site to depths of up to 0.7 metres.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The mapping only displays the flooding in the flow path to the west of Silverwater Road, which includes the backwater flooding from Parramatta River and Duck River. The Derby Street overland flows have not been quantified and are not shown. Floodway and flood storage areas are expected in Derby Street and Silverwater Road in the 1% AEP event which are likely to spread onto parts of the construction site.

3.3.5. Sydney Olympic Park metro station construction site

The Sydney Olympic Park metro station construction site is located on the boundary of the Haslams Creek and Powells Creek catchments. It is situated above the limit of mainstream flooding and has been assessed as being subject to minor overland flooding only, given its location on an elevated hill. Ground elevations on the construction site are 16 – 25 metres AHD with a high point at the centre of the construction site which slopes away to the north and south. The construction site is currently occupied by several large commercial buildings and is bound by Dawn Fraser Avenue and Herb Elliot Avenue to the north, Figtree Drive to the south and existing commercial properties to the east and west.

The construction site is not included in the study area extents of available flooding studies, hence depths and patterns of overland flooding have not been quantified. However, given the topographic location of the construction site, the flow conditions are expected to be shallow and benign, and mainly limited to within drainage gutters in the road corridors. There are no natural overland flow paths affecting the construction site.

As no previous flood studies are available for this construction site, mapping data of flood prone land, flood hazard, flood planning areas and floodway/flood storage areas is not available. Given the site location the

construction site appears to be outside the floodplain and hence is expected to be outside of high hazard, floodway and flood storage areas.

3.3.6. North Strathfield metro station construction site

The North Strathfield metro northern and southern construction sites are located adjacent to Queen Street on relatively high ground near the eastern edge of the Powells Creek catchment. The sites are bound by the rail corridor (T9 Northern Line) to the west, Queen Street to the east and Pomeroy Street to the north. The construction sites consist of operational uses related to the rail corridor and rail infrastructure. The sites are higher on the Queen Street side and slope down towards the railway. Elevations on the sites range from 14 to 20 metres AHD. Surrounding properties include commercial and residential properties on Queen Street and other streets to the east.

The construction sites are affected predominantly by minor overland flooding from catchment runoff from Queen Street, to depths of 0.1 metres in the 1% AEP flood event and up to 0.3 metres in the probable maximum flood. The northern end of the northern construction site is affected by major overland flooding due to a trapped drainage point being formed between the sloped road embankment of Queen Street and retaining wall structures along the rail corridor boundary. Ponding is up to depths of one metre in the probable maximum flood, which could be resolved with stormwater drainage.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The construction sites are rated as low hazard in the 1% AEP flood event and predominantly low hazard in the probable maximum flood, with areas of high hazard in the trapped ponding area in the north of the construction sites. While the construction sites are inside the modelled catchment area in the Jacobs (2015) flood study, they are outside the defined study area for that project. Hence, hydraulic category (floodway and flood storage) mapping at and around the construction sites was not defined as a part of the previous study. Interpretation of the flooding conditions indicates that the construction sites are outside of floodway or flood storage areas in the 1% AEP event.

3.3.7. Burwood North Station construction site

The Burwood North Station construction site is located in the St Luke's Park Canal catchment. It is situated on a hillside to the east of the canal and is well elevated above the canal. The site is split into two construction sites with the northern construction site bound by Parramatta Road to the south, Burwood Road to the west, Loftus Street to the east and Burton Street and existing medium-density residential properties to the north. The southern construction site is bound by Parramatta Road to the north, Burwood Road to the west, Esher Lane to the south and an existing commercial property to the east. The northern construction site is surrounded by commercial land use in addition to two medium-density residential properties, while the southern construction site is occupied by commercial properties. The surrounding area includes commercial properties along Parramatta Road and low and medium residential properties set back away from Parramatta Road. Immediately to the east is open space and recreational land use including Concord Oval. Ground elevations at the site range from 6.5 to 17 metres AHD and generally slope to the southeast.

Assessment of terrain data concludes that there are no natural overland flow paths affecting the site and surrounding areas, and minor overland and drainage flows are expected to be contained within the roadways. Previous flood studies (*WestConnex M4 Environmental Impact Statement*, Lyall & Associates, 2015) indicates minor overland flows within Parramatta Road on the southern side of the site, with flow depths of 0.2 metres in the 1% AEP flood event and 0.3 metres in the probable maximum flood, mostly contained in the roadway. An area of ponding is shown on an existing shop car parking area within the northern construction site which is considered a localised drainage issue and which can be mitigated by appropriate drainage or site grading.

The northern construction site and the area draining to it is not assessed in existing flood studies, but is expected to be affected by minor overland flooding only. The northern construction site is not affected by major overland or mainstream flooding.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The existing study mapping indicates minor overland flows in the southern side of Parramatta Road are contained in the roadway. Given the proximity of the northern construction site to the catchment ridge to the north-west, it is assumed that overland flows around other sections of that site would similarly be contained in the roadways. The existing study mapping indicates the sites are outside of high hazard and floodway/flood storage areas.

3.3.8. Five Dock Station construction site

The Five Dock Station eastern and western construction sites are both located near the top of a ridge of a local overland flow sub-catchment which drains to Hen and Chicken Bay to the north. Being near the top of a ridge, the construction sites are situated away from any natural overland flow paths.

The western construction site is located between Great North Road and East Street, to the north of Fred Kelly Place and south of St Albans Anglican Church. This site is currently occupied by commercial premises. The western construction site is at ground elevations of 17 to 20 metres AHD. The surrounding areas include commercial properties along Great North Road and low and medium density residential properties set back from the Great North Road.

The eastern construction site is bounded by Waterview Street to the east and Second Avenue to the north, with commercial buildings to the west and residential properties to the south. The eastern construction site is at ground elevations of 16.5 to 19 metres AHD. The eastern construction site is currently occupied by low and medium-density residential properties.

The construction sites are not covered by previous overland flood study modelling and mapping. Assessment of terrain data concludes that the construction site may be subject to minor drainage flows, which is likely to be confined to within the road corridors. Flood depth/extent, flood hazard and hydraulic categories have not been quantified for the site, although given the location of the construction site it is unlikely to be affected by high hazard, floodway or flood storage areas.

3.3.9. The Bays Station construction site

The Bays Station construction site is situated at the head of White Bay and is bound by the bay to its north-east, Robert Street to the north, the former White Bay Power Station site to the west and Victoria Road to the south. Surrounding land use includes commercial properties to the north and north-west and docklands to the east and north.

The adjacent former White Bay Power Station site is situated on low-lying land (about one to 1.5 metres lower than the construction site) which appears to be an overland flood ponding area for a 60 hectare sub-catchment that extends to the north-west into Rozelle, and hence parts of the site are expected to be subject to major overland flooding. The low-lying area appears to drain out via trunk drainage and overland via Robert Street around the northern end of the construction site to White Bay.

Flood depths of up to 0.4 metres occur in the 1% AEP event in the western side of the construction site, adjoining the former White Bay Power Station. Depths of up to 0.5 metres occur at the site vehicle entry point off Robert Street at the northern corner of the construction site, while depths of 0.5 to 0.7 metres occur at the eastern end of the construction site. Peak 1% AEP flood levels are about 3.2 metres AHD at each location on the site.

In the probable maximum flood event, flood depths of up to one metre occur in the western areas of the construction site, adjoining the former White Bay Power Station site. Depths of up to 0.9 metres occur at the proposed site vehicle entry point off Robert Street at the northern corner of the site, while depths of 0.7 to 0.9 metres occur at the eastern areas of the construction site. Peak probable maximum flood levels vary from about 3.4 to 3.9 metres AHD across the site.

Flood depth mapping and flood hazard mapping is presented in Appendix A. The flood hazard is generally low across the site in the 1% AEP event with localised area of high hazard at the eastern areas of the construction site. In the probable maximum flood event, there are areas of high flood hazard on the construction site as a result of a combination of relatively depths and velocities. Hydraulic category mapping information from the *Leichhardt Flood Study – Final Report* (Cardno, 2015b) indicates flood storage areas on the deeper ponding areas on the construction site in the 1% AEP, with floodway areas in Robert Street including the vehicle entry point to the site. In the probable maximum flood there are both floodway and flood storage areas on the construction site.

Low-lying parts of the construction site are at two metres AHD, which is expected to be affected by coastal inundation, assuming an elevated 1% AEP flood event ocean level of 1.45 metres AHD (OEH, 2015) plus one metre allowance for wind and wave effects. Higher parts of the construction site are sufficiently elevated and are not considered to be exposed to coastal inundation.

4. Construction impacts

4.1. Potential risks at construction sites and impacts of construction activities on flood behaviour

Physical features associated with Stage 1 may temporarily impact on flooding behaviour during construction due to features obstructing and redirecting flood flows, resulting in increases in flood depths and flow velocities. Permanent changes to flood behaviour would also occur due to the construction of the dive structure and tunnel portal at Rosehill, crossings of A'Becketts Creek and Duck Creek, a services facility and land formation works proposed at the Clyde stabling and maintenance facility construction site, which are included in Stage 1. The latter would also result in the reduction in available floodplain storage.

Key features of Stage 1 that may have an impact on flooding include:

- Fill embankment formations and modifications to current site grading
- Temporary noise barriers, acoustic sheds (proposed at some sites), site hoardings
- Temporary material stockpiles
- Temporary flood protection measures (e.g. retaining walls) around the excavations (e.g. shafts)
- Permanent flood protection measures (e.g. retaining walls) around the dive structure
- Temporary and permanent drainage and flow diversion works
- Other temporary construction phase features or structures being constructed for the operation phase (e.g. new crossings at A'Becketts Creek and Duck Creek)
- Paving of currently pervious areas, resulting in increased runoff volumes during flood events
- Formalised drainage speeding up runoff rates for local site drainage which may increase peak flows downstream.

Each site would include excavation from the surface to the tunnels underground (e.g. excavation for future stations, station entrances or service facilities, or for the tunnel dive). The excavated voids themselves would not impact flood behaviour, but the supporting structures at construction sites such as acoustic sheds and flood protection measures around excavated voids can affect flooding behaviour. While the majority of construction sites have existing buildings which may influence flood behaviour, changes to flooding behaviour around the construction sites may also occur due to alteration of the built form or due to the provision of new structures surrounding the entire site (e.g. hoardings), which would block off existing flow paths through the construction site. Civil construction works at Clyde would also involve the placement of fill material to meet the flood immunity design criteria as detailed in Section 2.2, which would alter flooding behaviour.

The flood impacts, without mitigation, due to increased flooding depths and flow velocities may affect adjacent properties, assets and infrastructure with potential increases in flood damage to properties and hazard to the public. The potential flood impacts from each construction site would depend on the elevation, topography and existing flow patterns at each site. Most of the construction sites are not affected by major flood flow paths and are not located within floodplain storage areas and therefore the overall risk of flooding impacts from Stage 1 is considered low and the magnitude of impacts negligible.

Flooding may also cause impacts on the construction sites themselves. The risks and impacts of flooding to the construction sites may range from minor, such as nuisance drainage problems, to more severe, including damage to the sites and construction facilities, ingress of significant volumes of floodwater into excavated voids and the tunnels underground, or construction materials and spoil being washed into nearby drainage lines and waterways. Where required, flood protection levels (estimated from the interpretation of available flood study

information) that are consistent with design criteria are identified in Table 4-1. The risks of flooding on the construction site and the potential impacts of each site to adjacent properties are summarised in Table 4-1.

Table 4-1: Potential construction stage impact summary

Construction site	Proposed works with potential to cause impacts	Discussion
Westmead metro station	• Site/noise hoardings around construction site boundary • Acoustic shed (or other acoustic measures) • Temporary material stockpiles.	• The construction site is outside the identified flood prone land and is not flood affected during the 1% AEP flood event or probable maximum flood. The construction site is subject to local drainage only. • Impacts to overland flooding behaviour on adjacent properties are unlikely. • The 1% AEP drainage flows would be contained in the adjacent roads, and a flood protection level of 0.5 metres freeboard above the top of kerb would be appropriate. • Direct intense rainfall onto construction site may cause nuisance flooding and drainage issues.
Parramatta metro station	• Site/noise hoardings around construction site boundary • Temporary material stockpiles.	• The construction site is flood-affected in 1% AEP flood event. There is potential for impacts to overland flooding behaviour on adjacent properties if flow paths through the site are modified from the existing case, for example, if the site access entrance allows flood flows to occur from the road sag point in Macquarie Street. • Potentially minor to moderate localised impacts in adjacent areas in probable maximum flood. The construction site is inundated to 1.5 metres depth in probable maximum flood. Flood impacts to surrounding areas may result from blocking or obstructing existing flow paths through the site, in particular Horwood Place between Macquarie Street and George Street and Macquarie Lane accessway to Smith Street. • Probable maximum flood flooding may impact on the construction site by inundation of the site and ingress of floodwaters into excavated void. Flood protection measures such as elevated entry into excavated void are required at this site to achieve the flood protection level. The flood protection level and feasible and reasonable protection based on the flood risks would be reviewed during detailed construction planning. The increase in probable maximum flood levels resulting from approved development including the Camellia Town Centre redevelopment, if it coincides with or before Stage 1, needs to be accounted for in the flood protection level. Refer to Section 4.8 for further discussion. • Direct intense rainfall onto site may cause nuisance flooding and drainage issues.

Construction site	Proposed works with potential to cause impacts	Discussion
Clyde stabling and maintenance facility	• Filled formation for the facility and floodplain crossings • Dive excavation, temporary dive flood protection measures and construction of the dive structure • Temporary noise hoardings • Temporary material stockpiles • Services facility shaft excavation, temporary shaft flood protection measures • Segment production facility • Temporary and permanent drainage and flow diversion works • Paving of currently pervious areas.	• Refer to Section 4.2 for further detailed discussion of the quantitative flood modelling of the Clyde site. • The filled formations would reduce floodplain storage and redirect flows particularly in the probable maximum flood. Minor impacts from these effects are expected in the 1% AEP event due to the lower flood-affectation of the site and surrounds in this event. Relatively minor impacts are expected in the probable maximum flood. This has been confirmed with quantitative flood modelling. • Formalising of the creek channels and provision of culvert crossings is expected to change flow conveyance capacities and velocities. The nature and degree of impacts would vary depending on the magnitude of the flood. • Large portions of the Sydney Speedway site and adjacent areas, which would form part of the Clyde stabling and maintenance facility construction site, are currently grassed or bare dirt which would be paved during construction phase. Paving of currently extensive pervious areas would increase site runoff rates and volumes, with potential to increase peak flood flows and levels downstream. • Current undulating landforms on the construction site would provide informal local drainage and flood storage. Regrading of the construction site is likely to remove these flood storage areas and may increase flooding downstream. • Formalised stormwater drainage on the construction site would also increase local catchment runoff rates which may increase peak flooding downstream. • The dive and tunnel portal and services shaft features are potentially exposed to inflows in up to the probable maximum flood. A flood protection level of the probable maximum flood level, as a minimum, has been adopted. • The top of filled embankment is required to be above the 1% AEP flood level plus 0.5 metres as a minimum to protect features and services on the facility. The top of embankment has been set with an elevation above the probable maximum flood, which is higher than the minimum required level.

Construction site	Proposed works with potential to cause impacts	Discussion
Silverwater services facility	• Potential modifications to current site grading and filling of the site • Shaft excavation, temporary shaft flood protection measures • Site/noise hoardings around site boundary • Temporary material stockpiles.	• The construction site is impacted by probable maximum flood flooding from the Parramatta River, and is also likely to be affected by major overland flooding. Floodwater ingress into the shaft could occur due to both overland flooding and mainstream flooding. • Previous flooding studies do not quantify overland flooding at the construction site, which is likely to be substantial. Future assessment is required to determine overland flood conditions and determine the flood protection level. The flood protection level and feasible and reasonable protection based on the flood risks would need to be reviewed during detailed construction planning. • Impacts to overland flooding possible but not expected to be major. Overland flows coming down Derby Street would be obstructed from spreading onto the construction site, but works on the construction site would not block the main flow path in the roadway. • Impacts to mainstream flooding unlikely due to site being on the fringe of the Parramatta River probable maximum flood extent and the relatively minor scale of works on the construction site. • Direct intense rainfall onto site may cause nuisance flooding and drainage issues.
Sydney Olympic Park metro station	• Site/noise hoardings around site boundary • Acoustic sheds covering parts of the excavated void (or other acoustic measures) • Temporary material stockpiles.	• The construction site is outside the identified flood prone land and is not flood affected during the 1% AEP flood event or probable maximum flood. The construction site is subject to local drainage only. • Impacts to overland flooding behaviour on adjacent properties unlikely. • The 1% AEP flood drainage flows would be contained in the adjacent roads, and a flood protection level of 0.5 metres freeboard above the top of kerb would be appropriate. • Direct intense rainfall onto the site may cause nuisance flooding and drainage issues.

Construction site	Proposed works with potential to cause impacts	Discussion
North Strathfield metro station	• Potential modifications to current site grading • Site/noise hoardings around site boundary • Temporary material stockpiles.	• The construction sites are affected by minor overland flows overflowing from Queen Street. The sites currently slope away from Queen Street and to the west. Overflow depths are shallow and flow rates appear to be low. • There is the potential for minor impacts to overland flooding behaviour on adjacent areas. • Impacts may be caused from site hoarding blocking overflows from Queen Street, resulting in increased ponding in the street. Overflows from Queen Street may cause damage to the construction site and ingress of water into the shaft. • The flood protection level and feasible and reasonable protection based on the flood risks would be reviewed during detailed construction planning. At this site, the 1% AEP flood levels plus 0.5 metres freeboard would be greater than the probable maximum flood level. • Direct intense rainfall onto sites may cause nuisance flooding and drainage issues.
Burwood North Station	• Potential modifications to current site grading • Site/noise hoardings around site boundary • Acoustic sheds covering parts of the excavated void (or other acoustic measures) • Temporary material stockpiles.	• The construction sites are outside main flow paths and are considered to be subject to minor overland flows and drainage flows only. • Impacts to overland flooding behaviour in adjacent areas are unlikely. • Existing minor overland flows are expected to be contained within roadways. The 1% AEP flood drainage flows would be contained in the adjacent roads, and a flood protection level of 0.5 metres freeboard above the top of kerb would be appropriate. • It is unlikely for significant flow paths to be present through the existing sites. Work at the construction sites is unlikely to disturb existing flow patterns and impact on adjacent properties. • Direct intense rainfall onto site may cause nuisance flooding and drainage issues.

Construction site	Proposed works with potential to cause impacts	Discussion
Five Dock Station	• Potential modifications to current site grading • Site/noise hoardings around site boundary • Acoustic sheds (or other acoustic measures) • Temporary material stockpiles.	• The construction sites are located at the top of a ridge and are outside of flood prone land. The sites are considered to be subject to local drainage flows only. • Impacts to overland flooding behaviour in adjacent areas are unlikely. • Existing minor drainage flows are expected to be contained within roadways. The 1% AEP flood drainage flows would be contained in the adjacent roads, and a flood protection level of 0.5 metres freeboard above the top of kerb would be appropriate. • It is unlikely for significant flow paths to be present through the existing sites, and flows into shafts are considered unlikely or minor. Work at the construction sites is unlikely to disturb existing flow patterns and impact on adjacent properties. • Direct intense rainfall onto site may cause nuisance flooding and drainage issues.

Construction site	Proposed works with potential to cause impacts	Discussion
The Bays Station	• Potential modifications to current site grading and filling of the site • Site/noise hoardings around site boundary • Acoustic sheds covering parts of the excavated void (or other acoustic measures) • Temporary material stockpiles.	• The construction site is affected by major overland flooding and local drainage, and is subject to coastal inundation. Based on available mapping, the construction site would be partially impacted during the 1% AEP flood event and mostly affected during the probable maximum flood as a result of significant overland flood flows originating from the gully extending up into Rozelle. • If raising and regrading of the site is required as part of Stage 1, this could potentially impact overland flooding on adjacent properties and roads. This is likely to increase overland flooding depths in the low-lying area adjacent to the site, particularly in the probable maximum flood, due to reduced floodplain storage. • An existing internal road within the construction site is proposed to be modified prior to the establishment of the construction site. The relocation of this road is subject to a separate planning approval. • The construction site does not appear to be in a significant flow conveyance area. As such, site hoardings and acoustic sheds are unlikely to obstruct flows. However, solid site hoardings may reduce effective floodplain storage in low-lying areas of the site. • Overland flows across the site which may occur in the 1% AEP flood event and greater could damage the construction site and facilities. Floodwater ingress into station excavation could occur due to overland flooding or coastal inundation. • The flood protection level and feasible and reasonable protection based on the flood risks would be reviewed during detailed construction planning. The flood protection level varies across the site and is required to be the greater of the probable maximum flood level and of the 1% AEP flood level plus 0.5 metres freeboard, and ranges from 3.7 to 3.9 metres AHD. Consideration in the protection level would also be required to account for coastal inundation (estimated at a minimum level of around 2.45 metres AHD which includes allowances for wind and wave effects). • Direct intense rainfall onto site may cause nuisance flooding and drainage issues.

4.2. Clyde stabling and maintenance facility

4.2.1. Description of works

Hydraulic modelling was undertaken for Stage 1 of the Clyde stabling and maintenance facility, which involves a number of permanent works, including:

- Filled formation at Clyde stabling and maintenance facility site, constructed to a finished level of 8.3 metres AHD (top of rail)
- A dive structure and tunnel portal to the north of the stabling and maintenance facility located between Rosehill Gardens racecourse and James Ruse Drive. The top of rail level at dive crest would be at 8.3 metres AHD, set based on a flood protection level of the probable maximum flood level at the dive crest and allowing for thickness of track slab and track height. Flood-proofing retaining walls would surround the dive structure and tunnel portal
- Land formations to cater for the future metro rail tracks into and out of the maintenance and stabling facility would cross Duck Creek and A'Becketts Creek at their confluence. The future tracks would continue north from the crossing to the dive structure and tunnel portal, then descend underground to join the Sydney Metro West mainline tunnels between Parramatta metro station and Sydney Olympic Park metro station
- New culvert crossing structure for the future tracks. The structure indicatively consists of twin six metre high by nine metre wide arch culverts on each creek channel. Both creek channels would be realigned at their confluence to realign their flow paths, including sections of open channel to the south of the proposed creek crossings. A new open channel to the north of A'Becketts Creek would also be constructed to convey floodplain flows originating from areas to the west of James Ruse Drive. This would be designed for events up to and including the probable maximum flood event. The open channels and culverts discharge to Duck Creek downstream of the Duck Creek and A'Becketts Creek crossing
- Unwin Street would be reconstructed to provide public road access around the Clyde stabling and maintenance facility. The reconstructed road would cross over the future rail tracks connecting the stabling and maintenance facility and the tunnel dive via a bridge structure, with a filled embankment constructed at the northern bridge approach. The southern bridge approach would form part of the stabling and maintenance facility filled embankment.

Refer to Appendix B for design details and layout.

The existing case TUFLOW model was updated to represent the operational phase features. This model was used to determine the potential flood impacts without additional flood impact mitigation works and measures.

4.2.2. Summary of flooding impacts

Mapping showing the flood impact (change in flood levels) and change in flood hazard is presented in Appendix B for the 5% and 1% AEP and probable maximum flood events. Outcomes of the design case modelling are discussed in the following sections.

4.2.2.1. Change in peak flood levels

Peak flood levels on the Duck Creek and A'Becketts Creek floodplains upstream of the Clyde stabling and maintenance facility are reduced in the 5% and 1% AEP events, by up to 0.1 metres, as a result of Stage 1. This is caused by the new crossings and formalising of sections of the creek channels, which would increase the flow capacity of the channels for these flood events.

There are increases in flood levels in the 5% and 1% AEP event of up to 0.08 metres in and adjacent to Duck Creek and Duck River downstream of the culvert crossings. Encroachment of the stabling and maintenance

facility filled embankment on the creek bank, at a location 500 metres upstream of the Duck Creek and Duck River confluence, contributes to the increased flood levels due to reduction of floodplain storage and reduction of floodplain flow conveyance. Opportunities to minimise increases at private property would occur during detailed design and would be informed by floor level surveys of existing properties (refer to Section 5).

These flood level increases extend back up Duck River to upstream of the M4 Motorway, with an increment in the 5% and 1% AEP flood levels of 0.01 to 0.02 metres, but do not affect any new properties in this area.

In the probable maximum flood event, flood levels are increased both upstream and downstream of the Clyde stabling and maintenance facility construction site as a result of reduction in flow conveyance on the floodplain due to the obstruction by the filled embankment of the stabling and maintenance facility and the new road bridge embankment. Loss of floodplain storage due to the embankment is also likely to contribute to the impacts. The change in flood levels include up to 0.07 metres increases in the A'Becketts Creek floodplain, up to 0.15 metres in the Duck Creek floodplain upstream of the culvert crossing, up to 0.06 metres in Duck Creek downstream of the culvert crossing and up to 0.1 metres in the Duck River floodplain, upstream of the M4 Motorway. Increases of up to 0.2 metres occur on the south-western section of Rosehill Gardens racecourse grounds. These flood level increases do not result in a significant impact to the flood hazard or trafficability of roads and emergency access routes (refer to Section 4.2.2.3 and Section 4.5) since the affected roads are already impacted by high flood depths and hazard in the existing case. Hence these are considered tolerable increases in the probable maximum flood.

Maximum increases in flood levels in the probable maximum flood are around 0.5 metres as a result of Stage 1. These effects are localised and occur in currently flooded areas under the James Ruse Drive viaduct, and do not impact on private property.

4.2.2.2. Change in flood extent

Increases in peak flood levels as a result of Stage 1 are relatively small in increment, resulting in minimal increases in the flood extent for all events up to the probable maximum flood. Maximum increases in the probable maximum flood extent are around 10 metres, and typically less than five metres.

4.2.2.3. Change in flood hazard

The change in flood hazard has been mapped to indicate areas where flood hazard increases from low (considered a H1 and H2 hazard rating, refer to Figure 2-2) to high (H3 rating and higher on Figure 2-2), and where the flood hazard decreases from high to low.

The increase in high flood hazard extent as a result of Stage 1 is generally minor in the 5% and 1% AEP and probable maximum flood events. There are areas with reductions in the high hazard extent in the 5% and 1% AEP events. Roads are generally affected by only marginal increases in the extent of the high flood hazard areas. There are no new roads which become significantly affected by high hazard flooding as a result of Stage 1.

4.2.2.4. Change in duration of inundation

Substantial increases in the duration of inundation can result in increased flood damage to property due to the longer exposure to floodwaters. The 1% AEP flood depth has been plotted against time over the course of the flood event at four selected locations on A'Becketts Creek, Duck Creek and Duck River on Figures B-18 to B-20 in Appendix B.

The plots show that the flood depths vary over the course of the flood events in a similar manner in both the existing case (without Stage 1) and the developed case (with Stage 1). There are slight increases in the duration of inundation on two locations on Duck River of less than 10 minutes, although these are not substantial increases. Flooding durations are not increased elsewhere. Hence, it is not expected that there would be significant increases in the duration of flooding or a resulting increase in flood damages as a result of Stage 1.

4.2.2.5. Impacts to property

Increases in flood levels and depths in the 5% and 1% AEP events as a result of Stage 1 are generally minor, with some industrial properties adjacent to Duck River in Auburn expected to experience minor increases of 0.01 to 0.02 metres (located upstream of Stage 1). The largest increase in flood levels is around 0.08 metres which occurs near the Duck Creek and Duck River confluence. This affects several commercial and industrial properties outside of the construction site. These increased flood levels appear to be below the floor levels of existing buildings affected, based on ground levels and site observations. Floor level survey would be completed during the design process to confirm the predicted impacts. Design refinement would be considered at detailed design stage to mitigate these flood level increases and potential impacts to properties where feasible and reasonable.

Flood level increases on properties in the probable maximum flood event are generally 0.04 to 0.08 metres, with a maximum increase of 0.2 metres occurring in the Rosehill Gardens racecourse. Given the rarity of such an event and the high depths and wide extent of flooding in this event, it is expected that there would be significant flooding damage already in the existing case and the resulting increase in flood levels due to Stage 1 would not cause a material increase in flooding impacts to property.

There are approximately seven properties which would become newly-affected by flooding in the probable maximum flood. No new properties were identified as becoming flood-affected in up to the 1% AEP event as a result of Stage 1.

4.2.2.6. Impacts to critical infrastructure

Critical infrastructure in the vicinity of the Clyde stabling and maintenance facility construction site consists of the existing rail line, Clyde Terminal and major roads, including M4 Motorway, Parramatta Road and James Ruse Drive. An existing B-double route from Parramatta Road to the Clyde Terminal via Wentworth Street and Unwin Street would be realigned as a part of Stage 1 and is also identified as critical infrastructure.

As described in Sections 4.2.2.1 to 4.2.2.4, the flood level, extent and hazard increases as a result of Stage 1 are minor in up to and including the probable maximum flood including at the critical infrastructure locations, considering that flood depths and hazard are already high in the existing case. Hence no significant impacts to critical infrastructure are expected as a result of Stage 1.

4.2.3. Climate change impacts

The probable maximum flood level at the tunnel dive crest in the current climate is 7.08 metres AHD, while the probable maximum flood level at the stabling and maintenance facility varies from 5.85 metres AHD to 6.55 metres AHD. The modelling indicates that the dive structure and tunnel portal and the stabling and maintenance facility site is above (in elevation) the influence of sea level rise of 0.9 metres in the year 2100. Therefore under the climate change scenario, with sea level rise, the probable maximum flood level remains at existing levels. Hence, no increase in the flood protection level is required to account for the effects of climate change on flooding.

4.3. Velocity and scour

Increases in flow velocity and scour potential may result where Stage 1 features alter flood flow patterns and significantly divert or concentrate flood flows. In general, the majority of construction sites are not located within or adjacent to major overland or mainstream flow paths. As such, there is overall a low potential to impact on flows and increased velocities and scour is not expected in floods up to the 1% AEP flood event.

Flow velocities are expected to increase at the Clyde stabling and maintenance facility construction site due to increased flow conveyance at the new crossings of A'Becketts Creek and Duck Creek and formalising sections of these creek channels, in addition to the new open channel for floodplain flows to the north of A'Becketts Creek.

Increased smoothness of the waterways due to the concrete lining of the culverts and clearing of vegetation from the channel would contribute to the increased velocities. Flow velocities at the culvert outlet are estimated to increase by about 18 percent from 0.8 metres per second to over 0.9 metres per second in the design 1% AEP event, which assumes coinciding high tailwater levels due to elevated ocean levels or Parramatta River flooding. Flow velocities and increases in velocities may be higher with lower tailwater levels. In addition, there is potential for localised scouring of bed material at the transition from hard drainage structures to the natural or unlined channel surfaces. Appropriate measures would be incorporated into the detailed design so that the potential impacts from increased downstream velocities and scour are mitigated.

4.4. Compatibility of sites with flooding conditions

In general, it is prudent for the construction sites to be situated away from areas of high flood hazard to minimise any risk to the safety of the public and of flooding damage to site. Works should also generally avoid main areas of flow conveyance (floodways) or flood storages in order to minimise any effects of the works on flood behaviour and hence impacts to flooding conditions on adjacent existing development. If this cannot be avoided, then the works should be designed appropriately incorporating mitigation strategies into the design to minimise potential impacts.

The compatibility of the construction sites with the flooding conditions in their locations is assessed in Table 4-2. Assessment of compatibility is based on exposure of the site to high hazard or high risk flooding, potential impacts of the construction site on flooding behaviour on surrounding properties, the impact of flooding on the sites, and ability to provide effective mitigation measures.

Table 4-2: Compatibility of sites with flooding conditions

Construction site	Flood affectation	Compatibility with flooding conditions
Westmead metro station	Not flood affected.	Compatible due to site being not flood-prone.
Parramatta metro station	Generally affected by shallow flooding less than 0.2 metres deep in the 1% AEP flood extent, with some areas of deeper flooding. Affected by probable maximum flood to depths of 1.5 metres.	Compatible due to generally low flood risk. Flooding depths in the 1% AEP event are generally shallow. Potential flooding impacts are expected to be minor and manageable. Mitigation measures can be implemented to protect the site from the effects of deeper floodwaters up to the probable maximum flood, and to minimise the impacts of the construction site on adjacent properties.

Construction site	Flood affectation	Compatibility with flooding conditions
Clyde stabling and maintenance facility	Mostly unaffected by mainstream flooding in the 1% AEP event. The construction site is mostly outside of mainstream floodway areas, although proposed works on the site would impede some floodplain flow paths and flood storage areas. The construction site is high hazard in the probable maximum flood. Proposed embankments and new creek crossings on Duck Creek and A'Becketts Creek have the potential to impact on probable maximum flood behaviour. The site is at low risk from overland flooding in up to the probable maximum flood. Minor exposure at tunnel dive site.	Detailed flood modelling of the construction and operational phase of the facility as discussed in Section 4.2 indicates that potential impacts to flooding are relatively minor. Further design refinement during future detailed design stages of the site are expected to provide further mitigation of flooding impacts. Based on the above, the impacts to flooding and the impacts from flooding on the construction site are considered manageable and hence the proposed works on the site are compatible with the flooding conditions of the site.
Silverwater services facility	Construction site is expected to be affected by overland flooding, which has not been quantified in previous flood studies. The site appears to be adjacent to, but not within, the main overland flow path. The construction site is affected by mainstream flooding in the probable maximum flood to depths of up to 0.7 metres.	Further assessment of flooding conditions and flood hazard on the construction site is required to fully confirm compatibility with the proposed works on the site. However, given the construction site is not within the main overland flow path, it is expected that mitigation measures can be provided to achieve compatibility with the flooding conditions.
Sydney Olympic Park metro station	Outside existing flood study areas. Review of terrain indicates not flood affected.	Compatible due to site being not flood-prone.
North Strathfield metro station	Mostly low hazard at both sites in up to probable maximum flood. Some areas of high hazard in the trapped ponding area in the north of the construction site which could be resolved by provision of drainage.	Compatible due to generally low hazard in up to probable maximum flood, with mitigation measures likely to manage some higher flood hazard in the probable maximum flood.

Construction site	Flood affectation	Compatibility with flooding conditions
Burwood North Station	Minor overland flows are contained in the roadway in the southern side of Parramatta Road and hence do not directly affect the sides of the northern and southern sites fronting Parramatta Road. Given the surrounding terrain, it is assumed that overland flows around the sides of the northern and southern sites away from Parramatta Road would similarly be contained in the roadways. Both sites are outside of high hazard and floodway/flood storage areas.	Compatible due to low hazard flows expected in events up to probable maximum flood and overall low flood exposure.
Five Dock Station	Outside existing flood study areas. Review of terrain indicates both the western and eastern sites potentially minor overland flood affected only.	Compatible due to low hazard flows expected in events up to probable maximum flood and overall low flood exposure.
The Bays Station	Low to moderate risk from overland flooding. Construction site mostly flood-free in 1% AEP flood event with some localised areas of ponding, but inundated to depths of 0.7 to 0.9 metres in probable maximum flood. The station box is located on higher parts of the site and are not considered to be exposed to coastal inundation.	Compatible. Flood depths and hazard are generally low on the site in up to the 1% AEP flood event. Mitigation measures can readily be provided to manage flood risk due to overland flooding and combined coastal inundation events in up to probable maximum flood.

4.5. Potential impacts to emergency management arrangements for flooding

Impacts to flood emergency management arrangements could occur as a result of Stage 1 if there would be increased flood depths, flow velocities or longer times of inundation resulting in increased durations of roads and evacuation routes being inaccessible for vehicles. Changes to flooding behaviour could also impact on critical services (e.g. hospitals, emergency services depots and evacuation centres) and sensitive properties requiring particular emergency planning consideration (e.g. schools, day care centres, nursing homes).

As discussed in Section 4.1, flood impacts from Stage 1 are expected to generally be minor. As a result, the impacts to flood evacuation routes and emergency facilities are generally expected to be unlikely or minor. This includes emergency routes associated with the Westmead Health Precinct. Where impacts could occur at specific construction sites in Stage 1, these potential impacts are summarised in Table 4-3.

Table 4-3: Potential flood impacts to emergency management arrangements

Construction site	Identified emergency management routes and facilities	Sensitive properties	Impact assessment
Parramatta metro station	Macquarie Street, Church Street, George Street and Smith Street identified as possible emergency access routes in immediate vicinity.	Sensitive properties in vicinity include Arthur Phillip High School, YMCA Child Care Services (Smith Street), Reggio Emilia Child Care (George Street), Goodstart Early Learning Parramatta.	Impacts to overland flooding unlikely in 1% AEP flood event. Impacts to emergency access routes, emergency facilities and sensitive properties unlikely in 1% AEP flood event. Potentially minor to moderate localised overland flood depth and velocity increases in probable maximum flood. Impacts to emergency arrangements unlikely due to significant flooding depths and high hazard already present in pre-development case. Probable maximum flood depths over 1.5 metres are typical throughout Parramatta CBD.

Construction site	Identified emergency management routes and facilities	Sensitive properties	Impact assessment
Clyde stabling and maintenance facility	James Ruse Drive, M4 Motorway, Parramatta Road identified as possible emergency access routes in immediate vicinity.	Sensitive properties in the vicinity include Rosehill Public School and Preschool, Fun2learn Early Learning Centre, Kinderoo, Little Angles Kindergarten, Rosehill Montessori Kindergarten.	Adverse impacts to emergency access routes, emergency facilities and sensitive properties are not expected in the 1% AEP flood event. Increases in flood depths on James Ruse Drive and Parramatta Road of up to 0.1 metres are expected in the probable maximum flood, although impacts to emergency arrangements are unlikely as significant flooding depths (over 1.5 metres) and high hazard are already present in pre-development case (without Stage 1). Part of the Kinderoo preschool is affected by an increase in probable maximum flood levels of 0.02 metres. No other identified sensitive properties are impacted.
The Bays Station	Main emergency access routes in the vicinity include Robert Street, Mullens Street and Victoria Road. No emergency services have been identified in the vicinity of the construction site.	No sensitive properties have been identified in the vicinity of the construction site.	Potential increase in flood depths in Robert Street east of Mullens Street, without appropriate mitigation measures.

4.6. Floodplain risk management

Local councils are responsible for identifying existing and future floodplain risk and providing measures and programs to manage or mitigate that risk within their local government areas, in line with the NSW Government's flood prone land policy and guided by the *Floodplain Development Manual* (NSW Government, 2005). This is done by undertaking floodplain risk management studies and developing and implementing floodplain risk management plans. Programs and measures typically include infrastructure works such as flood detention basins or improved trunk drainage to physically reduce flooding in problem areas. Other measures are of a planning, policy or organisational nature to reduce the exposure of people and property to flooding.

A review of publicly available floodplain risk management plans was undertaken to identify whether Stage 1 could potentially be in conflict or be inconsistent with the measures outlined in these floodplain risk management studies and plans. The review did not identify any conflicts or inconsistencies with the proposed measures of those plans with the exception of The Bays Station construction site. The *Leichhardt Floodplain Risk Management Study* (Cardno, 2017) identifies a proposed flood modification works option WB-FM1 (Beattie Street Branch drainage upgrade/duplication), which would involve proposed duplication of an existing 2.8 metre by 1.8 metre box culvert running under Robert Street that discharges to White Bay. This option has a medium priority (ranked nine out of 25) and may encroach on the northern boundary of the construction site, but is not expected to come into close proximity of station box excavation areas (located mid- to southern portion of the construction site). Potential conflicts would only arise if Stage 1 works and the construction of this option were to coincide.

4.7. Economic and social costs from flooding impacts

Based on the assessment of potential flooding impacts in Section 4.1, the potential flooding impacts which could result from Stage 1 are generally expected to be minor or negligible for most sites. Most sites have been identified as having a nil to low level of flood-affectation in events up to and including the 1% AEP flood event. Potential flood impacts in the probable maximum flood are expected to be relatively minor in comparison to the high magnitude of depths of flooding in this extreme event. Mitigation is identified which would further reduce these potential flood impacts and risks (refer to Section 5).

Peak flood levels in developed areas in the vicinity of the Clyde stabling and maintenance facility construction site are expected to typically reduce in up to the 1% AEP event as a result of changed drainage conditions, while there are other areas likely to experience minor increases of up to 0.02 metres in flood levels. There are some areas adjacent to Duck Creek and Duck River where flood levels in up to the 1% AEP event would increase by 0.08 metres, although this does not appear to result in any increases to above-floor flooding of affected buildings. The 1% AEP flood extent does not increase substantially with no new properties becoming flood-affected. Increases in flood levels in the probable maximum flood event are typically less than 0.1 metres, which are considered a low increment due to the existing high depths of flooding and the rarity of such flooding events. The increase in the probable maximum flood extent is minor and is also not expected to significantly increase the flood damages in that extreme flood event.

Given the generally low flood affectation of construction sites and expected low impact of Stage 1 on flood behaviour to surrounding properties and infrastructure, the impact of Stage 1 on societal and economic costs of flooding are therefore considered to be low.

4.8. Cumulative flooding impacts

A qualitative assessment of the potential cumulative flood impacts of Stage 1 with other proposed development has been undertaken. Cumulative impacts could occur as a result of other proposed developments interacting with the changed flood flow conditions caused by Stage 1. For example, blockage of flow paths near Stage 1 construction sites or cumulative loss of floodplain storage. The proximity of other proposed development to Stage 1 construction sites would increase the magnitude, extent and likelihood of cumulative impacts.

As discussed in Table 4-1, the flooding impacts resulting from Stage 1 are expected to be generally minor and localised at worst due to the low flood-affectation of the construction sites. Hence, cumulative impacts due to the combined effects of other proposed developments are unlikely, or expected to be minor and localised.

4.8.1. Approved and proposed developments

A review of approved and proposed developments and development projects in the vicinity of the Stage 1 sites is provided in Table 4-4. Those within about 300 metres of flood-affected Stage 1 construction sites are discussed for potential cumulative flood impacts. Those situated further away have been reviewed and are considered

unlikely to result in cumulative impacts given the nature of the proposed developments, their flood-affectation and the flood-affectation and impacts of the nearby Stage 1 construction sites.

The identified proposed developments in the vicinity of Stage 1 are mostly characterised as infill urban development and/or are not significantly affected by flooding in up to the 1% AEP event. Substantial proposed developments and those in close proximity are assessed in Table 4-4 for potential cumulative impacts in up to the 1% AEP event.

Table 4-4: Cumulative impact assessment of approved and proposed developments and current development projects

Project name	Description	Cumulative impact assessment
Parramatta Light Rail Stage 1	Parramatta Light Rail Stage 1 comprises a light rail network from Westmead to Carlingford and Camellia. Key features include light rail track and stops and shared light rail/pedestrian areas including in Macquarie Street. An integrated stabling and maintenance facility located in Camellia is also proposed.	The light rail alignment is adjacent to the Parramatta metro station construction site. Peak flood levels in the immediate vicinity of the Parramatta metro station construction site would reduce in Parramatta Light Rail post-construction conditions in up to the 1% AEP event (reference: *Parramatta Light Rail Flooding Technical Paper* (Arup, 2017)). This is likely to be due to proposed light rail track drainage and changes to the ground surface elevations as a result of the light rail. Hence, no or minimal cumulative impacts are expected in up to the 1% AEP event. The light rail stabling facility is about 500 metres from the Clyde stabling and maintenance facility construction site. The effects of Stage 1 does not interact with the potential impacts of the light rail stabling facility on overland flooding. No or minimal cumulative impacts are expected.

Project name	Description	Cumulative impact assessment
Parramatta Light Rail Stage 2	Extension of Parramatta Light Rail Stage 1 from Camellia to Sydney Olympic Park	Start of Parramatta Light Rail Stage 2 at Camellia (western end) is about 1 kilometre from Parramatta metro station construction site and 1.3 kilometres from Clyde stabling and maintenance facility construction site. It is sufficiently distant from these flood-affected Stage 1 construction sites that there are no cumulative impacts expected in up to the 1% AEP event. The eastern end of Parramatta Light Rail Stage 2 passes immediately adjacent to the Sydney Olympic Park metro station construction site, which is not flood-prone. Hence, no cumulative impacts are expected in up to the 1% AEP event.
99 - 119 Macquarie Street, Parramatta	The project involves a 14 storey mixed use (retail, office, student housing, group home and boarding house) building envelope at 99-113 Macquarie Street [Epworth House]; 13 storey mixed use (church administration, community facility, student housing, group home and boarding house) building envelope at 119A Macquarie Street [Fellowship Centre]; 2-6 storey basement envelope (retail, church administration and 142 parking spaces)	About 15 metres from the Parramatta metro station construction site. This proposed development site is not significantly affected by existing flooding in up to the 1% AEP event. No or minimal cumulative impacts are expected in up to the 1% AEP event.
89 George Street, Parramatta	The project involves the demolition of existing structures and the construction a 24-storey hotel building. The building would include accommodation, an ancillary restaurant/bar, outdoor terrace/pool, ballroom, and 69 above ground car parking spaces. The project includes landscaping works.	About 215 metres from the Parramatta metro station construction site. This proposed development site is not significantly affected by existing flooding in up to the 1% AEP event. No or minimal cumulative impacts are expected in up to the 1% AEP event.

Project name	Description	Cumulative impact assessment
6-7 Parramatta Square, Parramatta	Construction of a 56 storey commercial tower, including plant and a function centre on level 55. The development includes works within Darcy Street comprising service infrastructure diversions, rebuilding of Darcy Street roadway, kerb and footpaths, associated landscaping and public domain works, and provision and augmentation of physical infrastructure. The determining authority for the application is the Sydney Central City Planning Panel.	About 15 metres from the Parramatta metro station construction site, on opposite side of Macquarie Street. The proposed development is infill development on the subject site. No overland flow paths on subject site. Cumulative impacts with the Parramatta construction site may include localised changes to flood depths in Macquarie Street in up to the 1% AEP event.
Westfield Shopping Centre Parramatta Retail and Commercial development (Stage 1)	The project involves the staged extension of Westfield Shopping Centre Parramatta. The concept plan included in the proposal includes the following construction components: • An additional single level of retail uses over the existing shopping centre footprint • A 20-storey commercial tower above the retail podium • An additional 1,100 aboveground car spaces • Street activation and public domain works on the corner of Church and Argyle Streets. • Stage 1 involves the construction of the additional retail uses and car spaces described above.	About 200 metres from Parramatta metro station construction site. The proposed Westfield development is mainly within existing building footprint and not hydraulically connected to the Parramatta metro station construction site with respect to overland flooding. No cumulative impacts are expected.
New Powerhouse Museum, Parramatta	The proposal involves the construction and operation of the New Powerhouse Museum at the intersection of Philip Street and Wilde Avenue in Parramatta. The proposal includes 18,000 square metres of exhibition space.	About 240 metres from the Parramatta metro station construction site. No design details available for proposed development, however, it is affected mainly by river flooding and is not hydraulically connected to the Parramatta metro station construction site with respect to overland flooding. No cumulative impacts are expected.

Project name	Description	Cumulative impact assessment
Western Sydney University Innovation Hub (2B-6 Hassall Street, Parramatta)	The proposal involves the development of a mixed-use facility comprising a tertiary institution, commercial office space and retail space. The proposal includes the following construction components: • Construction of a 19-storey building • Landscaping and public domain works including a ground-level pedestrian plaza • Extension and augmentation of services and infrastructure as required.	About 320 metres from the Parramatta metro station construction site. The proposed development is infill development on the subject site and not hydraulically connected to the Parramatta metro station construction site with respect to overland flooding. No cumulative impacts are expected in up to the 1% AEP event.
Clyde Terminal Conversion Project	The project involves the removal of redundant crude oil refinery and import facilities at the Clyde Terminal and upgrade of existing facilities to allow for the receipt, storage and distribution of finished petroleum products. The project would result in a reduced operational footprint for the terminal. The project involves the following components: • Demolition of existing oil refinery processing units, surplus storage tanks and other redundant infrastructure • Upgrade of existing storage tanks and supporting infrastructure and utilities to be retained. • The project will also involve regrading and excavation of certain areas of the site up to 1 metre below ground level for drainage improvements.	About 220 metres from the Clyde stabling and maintenance facility construction site. Part of the proposed development site is affected by mainstream flooding in Duck River and Parramatta River in the 1% AEP event in current and future climate change conditions. Minor flood impacts of up to 0.02 metres increase in peak flood levels extend from the Clyde stabling and maintenance facility construction site onto the proposed development site in both current and future climate change conditions. Based on these flood impacts and the nature and flood-affectation of the proposed development it is expected that there would be no adverse cumulative flooding impacts in up to the 1% AEP event including in the future climate change scenario. There may be minor positive flooding effects as a result of the proposed development due to the proposed excavation of certain site areas and increased floodplain storage, if these areas are allowed to flood, particularly in the climate change scenario.

Project name	Description	Cumulative impact assessment
Viva Energy Clyde Western Area Remediation Project	The proposal involves the remediation of contaminated soils associated with former oil refinery activities to facilitate future development of the land for other purposes permissible under the existing land use zoning.	About 220 metres from the Clyde stabling and maintenance facility construction site. The proposed development site comprises part of the overall Clyde Terminal Conversion Project site described above. Similarly to the assessment for that proposed development, it is expected for the Viva Energy Clyde Western Area Remediation Project that there would be no adverse cumulative flooding impacts in up to the 1% AEP event including in the future climate change scenario.
North Strathfield Station Upgrade	The project involves accessibility upgrades to North Strathfield Station including the following components: • Three new lifts and associated weather canopies from the station platforms and Queen Street to the existing footbridge • Upgrade of existing platform surfaces • Modification to existing station buildings, canopies and installation of solar panels • Utilities works between Queen Street and the existing station buildings • Upgrade of existing footpaths at the Queen Street and Hamilton Street entrances • Adjustments to ancillary infrastructure.	Immediately adjacent to the North Strathfield metro station construction site. The works are now completed. No cumulative impacts are expected in up to the 1% AEP event.
Concord Oval redevelopment	The proposal involves the redevelopment of Concord Oval including the following components: • Facilities for the West Tigers rugby club • Match-day facilities for local sporting clubs • Multi-use indoor and outdoor community and sport facilities • Covered seating for sports spectators • Informal outdoor sports areas • Shared use paths.	About 40 metres from the Burwood North Station construction site. The proposed development consists of upgrades and modifications to existing station infrastructure. The Burwood North Station construction site are subject to minor overland flows and drainage flows only and impacts to overland flooding behaviour in adjacent areas are unlikely. Hence, no cumulative impacts are expected in combination with the proposed Concord Oval redevelopment in up to the 1% AEP event.

Project name	Description	Cumulative impact assessment
Five Dock Streetscape Upgrade – Stage 2	The project involves streetscape upgrade works to Great North Road and local roads between Queens Road and Henry Street. The project involves the following components: • Installation of new pavements and street furnishings • Planting of street trees and shrubs • Drainage improvements.	About 15 metres from the Five Dock Station construction site which are subject to minor overland flows and drainage flows only and impacts to overland flooding behaviour in adjacent areas are unlikely. Hence, no cumulative impacts are expected in combination with the proposed Five Dock Streetscape Upgrade Stage 2 in up to the 1% AEP event.
M4-M5 Link	The M4-M5 Link component of WestConnex involves the construction and operation of twin tunnels between the New M4 at Haberfield and the New M5 at St Peters, with an interchange at Rozelle and tunnel connection to Victoria Road at Iron Cove. Components of the project relevant to this cumulative impact assessment include: • Wattle Street surface works • Rozelle surface works • Iron Cove Link surface works • Ventilation facilities at Rozelle and Iron Cove.	About 30 metres from The Bays Station construction site. Flood modelling of the Rozelle surface works (reference: WestConnex – M4-M5 Link Technical working paper: Surface water and flooding (AECOM, 2017)) indicates minor (0.02 to 0.05 metres increase in flood levels) and localised impacts in the 1% AEP event along the verges of The Bays Station construction site but not near main areas of works. No cumulative impacts are expected in up to the 1% AEP event. The proposed development is situated a minimum of 800 metres away from Five Dock Station construction site and is not hydraulically linked to these Stage 1 construction sites. No cumulative impacts are expected in up to the 1% AEP event.
Extension to Longitude Office Building – 36 James Craig Road, Rozelle	This proposal involves alterations and extensions to an existing office building on James Craig Road, including: • 5-8 storey extension • Extension of existing floorplates • Internal alterations • Addition of green elements to facades and roof.	About 150 metres from The Bays Station construction site. Not hydraulically linked to Stage 1 construction site. No cumulative impacts are expected in up to the 1% AEP event.

4.8.2. Proposed local strategic plans

Local strategic plans were also considered where they may result in future development with potential cumulative impacts with Stage 1. The potential impacts from local strategic plans have not been considered in detail given the uncertainty of the status, timing, design and construction methods of associated projects.

Table 4-5 Cumulative impact assessment of strategic plans

Strategic plan	Description	Cumulative impact assessment
Westmead Innovation District: Building Western Sydney's jobs engine Strategic Vision 2016-2036	The Westmead Strategic Vision 2016-2036 is a 20-year plan developed by the NSW Government and the Westmead Alliance to guide investment decisions that support the growth of Westmead as a world class medical, educational and research precinct. The Westmead metro station construction site is located within the area covered by the Strategic Vision.	Cumulative flood impacts unlikely due to Westmead metro station construction site being subject to local drainage only.
Greater Parramatta Interim Land Use and Infrastructure Implementation Plan	The Interim Plan outlines actions to support the delivery of new homes, jobs, services and infrastructure in the Greater Parramatta and Olympic Park area. It includes a land use framework to guide future redevelopment of the priority growth area, identifies key actions for the short term and allows us and other government agencies to identify and plan for the infrastructure required. A number of construction sites for Stage 1 are located in the suburbs covered by the District Plan, including Westmead, Parramatta, Clyde, Silverwater, Sydney Olympic Park and North Strathfield.	Broad-scale urban strategic plan covering almost 6,000 hectare areas from Westmead to Strathfield. No specific cumulative flood impacts could be determined.
Parramatta North Urban Renewal Area Plan	The Parramatta North Urban Renewal Area Plan is a rezoning plan for government-owned land in Parramatta North developed by the NSW Government and UrbanGrowth. Key features of the plan include provisions for the adaptive reuse of heritage items, the development of a village centre and the construction of around 3,000 homes. The Stage 1 construction sites for Westmead metro station and Parramatta metro station are located in the vicinity of the land covered by the Parramatta North Urban Renewal Area Plan.	The strategic plan site is on the opposite side of the Parramatta River and largely above the 1% AEP flood level. There are unlikely to be cumulative flood impacts in up to the 1% AEP event.

Strategic plan	Description	Cumulative impact assessment
City of Parramatta Civic Link Framework Plan	The Civic Link Framework Plan provides a long-term aspiration, strategies, design ideas and recommendations for Parramatta's new public open space. The Civic Link extends about 500 metres long from Parramatta Square to River Square and the broader foreshore precinct. This new public open space runs along the existing Horwood Place alignment and will be made possible by the redevelopment of the above-ground Council-owned City Centre car park.	The proposed redevelopment would run through the Parramatta metro station construction site and provide a continuous straight corridor from Horwood Place at George Street to the drainage sag point on Macquarie Street. This may result in redirection of overland flows with localised flooding impacts in George Street in the 1% AEP event.
Draft Camellia Town Centre Master Plan	The Draft Camellia Town Centre Master Plan is 20- to 30-year plan developed by the NSW Government to establish a new town centre in Camellia. The draft Plan focuses on the establishment of Camellia Town Centre to ensure the renewal occurs in tandem with access and transport improvements such a bridge across Parramatta River, road improvements, and the creation of walking and cycling paths. The footprint for Clyde stabling and maintenance facility construction site is located in the vicinity of the land covered by the Draft Camellia Town Centre Master Plan.	The site is situated along the Parramatta River and is partially affected by the 1% AEP flood. Design information in the Master Plan and the *Camellia Town Centre Landfill Strategy Draft Flooding and Contamination Study* (Cardno, 2018) indicates a number of high rise residential complexes are proposed with filling and regrading of the ground surface. The proposed town centre is located at sufficient distance from metro station construction sites so that cumulative impacts are not expected in the 1% AEP event. The Camellia Town Centre site is significantly affected by the probable maximum flood event and is expected to have impacts on flood behaviour as a result of the development impeding the conveyance of flood flows through the floodplain. The probable maximum flood levels at the Parramatta metro station construction site could be expected to increase by up to about 0.5 metres, if Sydney Metro West construction coincides with, or follows, the Camellia Town Centre redevelopment. Future modelling is recommended to confirm impacts. The Camellia Town Centre development is located along the Parramatta River, and would not have cumulative flood impacts with the Clyde stabling and maintenance facility construction site which is on Duck Creek and Duck River.

Strategic plan	Description	Cumulative impact assessment
Sydney Olympic Park Master Plan 2030	The Sydney Olympic Park Master Plan 2030 is a plan developed by the NSW Government and the Sydney Olympic Park Authority to identify opportunities to transform Sydney Olympic Park into a thriving urban centre. The Master Plan includes the development of a new school, five additional or enhanced parks, employment opportunities, residential communities and retail developments. The footprint for Sydney Olympic Park metro station construction site is located are located within the area covered by the Master Plan. The Stage 1 construction sites for Silverwater services facility and North Strathfield metro station are located in the vicinity of the land covered by the Master Plan.	The nearby Stage 1 construction sites are not flood-affected or hydraulically connected to the strategic plan site. No cumulative flood impacts are expected in up to the 1% AEP event.
Burwood, Strathfield and Homebush Planned Precinct	The NSW Government is in the process of developing a precinct plan to guide land use controls and inform future development within the suburbs of Burwood, Strathfield and Homebush. It will build on Parramatta Road Corridor Urban Transformation Strategy and be developed in conjunction with the City of Canada Bay, Burwood and Strathfield Councils. The Stage 1 construction sites for North Strathfield metro station and Burwood North metro station are likely to be located within land covered by the future precinct plan. The Stage 1 construction footprint for Sydney Olympic Park metro station is likely to be located in the vicinity of the land covered by the future plan.	The strategic plan is in early stages of the planning process and specific cumulative flood impacts could not be determined.

Strategic plan	Description	Cumulative impact assessment
Parramatta Road Corridor Urban Transformation Strategy	The Parramatta Road Corridor Urban Transformation Strategy is a 30-year plan developed by the NSW Government and Landcom to drive and inform land use planning and development decisions as well as long-term infrastructure delivery programs in the Parramatta Road Corridor. The footprint for Burwood North Station construction site is located within land covered by the Strategy.	The Burwood North Station construction site is subject to minor overland flows and drainage flows only. Assuming existing drainage conditions are maintained in Parramatta Road, cumulative flood impacts are not expected in up to the 1% AEP event.
Five Dock Urban Design Study	The Five Dock Town Centre Urban Design Study was commissioned by the City of Canada Bay Council in 2013. The purpose of the Urban Design Study is to ensure that any potential changes to the existing planning controls were carefully considered, to identify improvements to the public domain, and consider opportunities for future redevelopment within the centre. The Five Dock Station construction site is located within land covered by the Urban Design Study.	The Five Dock Station construction site is subject to minor overland flows and drainage flows only. Assuming existing drainage conditions are maintained, cumulative flood impacts are not expected in up to the 1% AEP event.
The Bays Precinct Urban Transformation Plan	This 20- to 30- year plan provides for a mix of cultural, maritime, recreational, retail and commercial uses around eight waterfront locations including White Bay Power Station, Glebe Island, White Bay, Blackwattle (including Sydney Fish Market), Wentworth Park, Rozelle Bay, and Rozelle Railways. The NSW Government is currently conducting studies to inform development of The Bays Markets District (Blackwattle Bay) and White Bay Power Station, which cover locations relevant to this assessment.	The Bays Station construction site is within the former White Bay Power Station location. Cumulative flood impacts may occur if overall site regrading changes floodplain storage and flow paths, in addition to changes in drainage conditions.

5. Mitigation and management measures

Mitigation and management measures are proposed where appropriate to limit flooding impacts of Stage 1 on surrounding properties, in addition to limit the risk of flooding on the construction sites. These are provided in Table 5-1.

There is residual risk of flooding, after mitigation, at the Parramatta metro station, Clyde stabling and maintenance and The Bays Station construction sites in the 1% AEP flood event and up to the probable maximum flood.

As detailed in the Construction Environmental Management Framework (Appendix D of the Environmental Impact Statement), stormwater and flooding management plans would be prepared for construction sites at risk of flooding. These plans would:

- Identify the appropriate design standard for flood mitigation based on the duration of construction, proposed activities and flood risks
- Develop procedures so that threats to human safety and damage to infrastructure are not exacerbated during the construction period.

Table 5-1: Mitigation and management measures

ID	Mitigation measure	Applicable location[1]
HF 1	Detailed construction planning would consider flood risk at construction sites. This would include: • Identification of measures to not worsen flood impacts on the community and on other property and infrastructure during construction up to and including the one per cent AEP flood event • Provide flood-proofing to excavations at risk of flooding or coastal inundation during construction, where reasonable and feasible, such as raised entry into shafts and/or pump-out facilities to minimise ingress of floodwaters into shafts and the dive structure • Review of site layout and staging of construction activities to avoid or minimise obstruction of overland flow paths and limit the extent of flow diversion required. This includes design of site hoardings to minimise disruption to flow paths (if possible). Not worsen is defined as: • A maximum increase in flood levels of 50mm in a one per cent AEP flood event • A maximum increase in time of inundation on one hour in a one per cent AEP flood event • No increase in potential soil erosion and scouring from any increase in flow velocity in a one per cent AEP flood event.	PMS, CSMF, SSF, NSMS, TBS
HF 2	On-site stormwater detention would be provided for the Clyde stabling and maintenance facility construction site to manage peak site runoff rates and volumes due to increased imperviousness of the site.	CSMF

ID	Mitigation measure	Applicable location[1]
HF 3	Further design refinement at the Clyde stabling and maintenance facility construction site would occur during detailed design to mitigate the identified potential impacts including: • The increases in flood levels of up to 0.08 metres in Duck Creek and adjacent properties in the one per cent AEP flood • Increases in flow velocities and the potential increased risk of scour at the proposed creek crossings and in the downstream channels • The potential flooding impacts from filled features including the the road overbridge approach.	CSMF
HF 4	Drainage at construction sites would be designed, where feasible and reasonable, to mitigate potential alterations to local runoff conditions due to construction sites.	All
HF 5	Detailed construction planning for The Bays Station construction would aim to minimise changes to existing levels in relation to potential impacts on flood behaviour, along the north-western side of site adjacent to low-lying property, to minimise reduction in floodplain storage.	TBS
HF 6	Consultation would occur with the proponent of the Camellia Town Centre redevelopment to understand potential flood impacts from the development on Stage 1 and future stages of Sydney Metro West, and to identify any additional flood protection at the construction site (if required).	PMS
HF 7	Construction planning regarding flooding matters would be carried out in consultation with the NSW State Emergency Service and the relevant local council.	PMS, CSMF, TBS
HF 8	Detailed construction planning for The Bays Station construction site would aim to avoid conflicts with the potential construction of flood mitigation works in Robert Street, in consultation with Inner West Council.	TBS

[1] WMS: Westmead metro station; PMS: Parramatta metro station; CSMF: Clyde stabling and maintenance facility; SSF: Silverwater services facility; SOPMS: Sydney Olympic Park metro station; NSMS: North Strathfield metro station; BNS: Burwood North Station; FDS: Five Dock Station; TBS: The Bays Station; Metro rail tunnels: Metro rail tunnels not related to other sites (eg tunnel boring machine works); PSR: Power supply routes.

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Appendix A Flood mapping for Stage 1 construction sites

List of Flood Mapping Figures

Figure A-1: Westmead metro station - 1% AEP peak flood depths

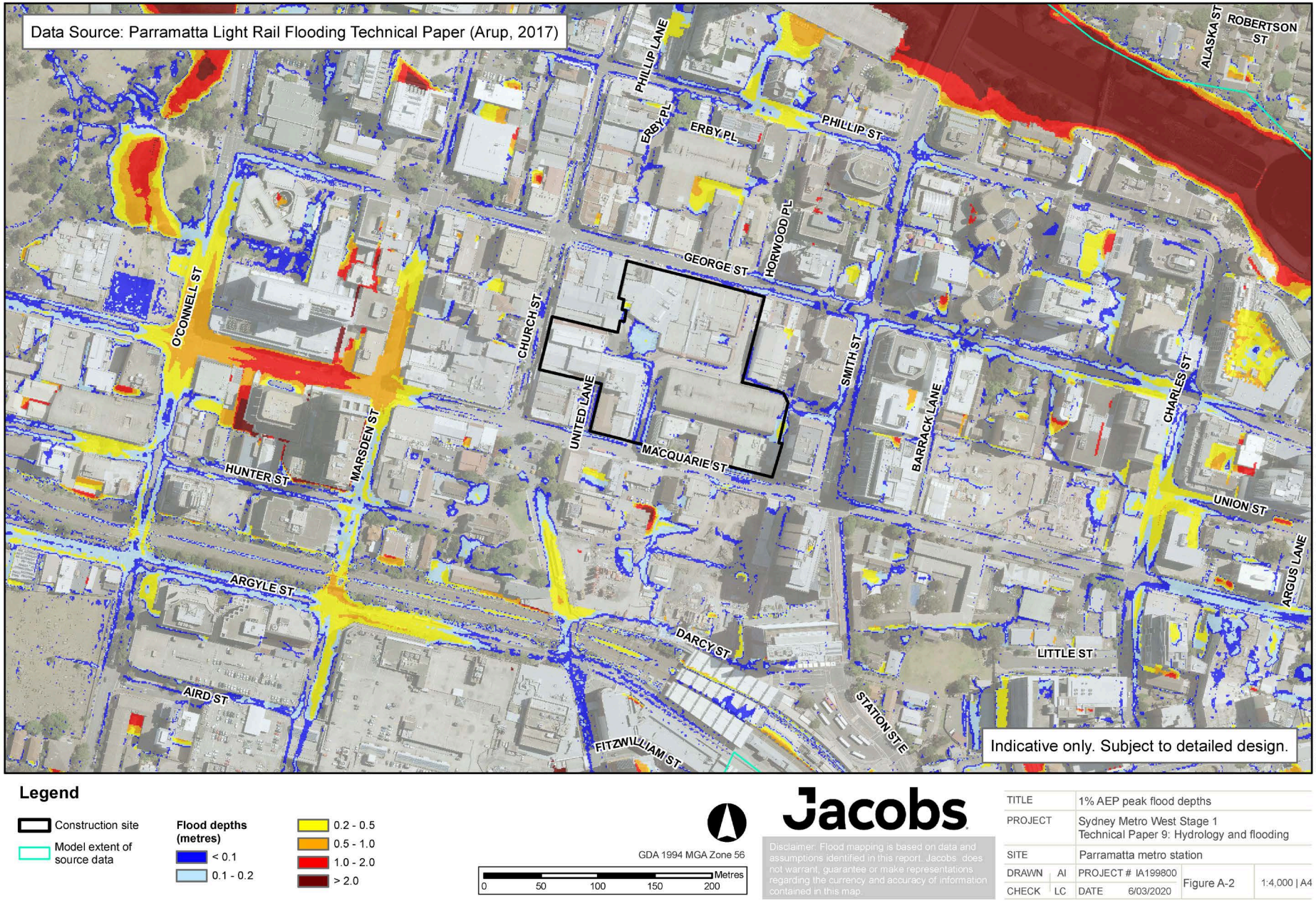


Figure A-2: Parramatta metro station - 1% AEP peak flood depths

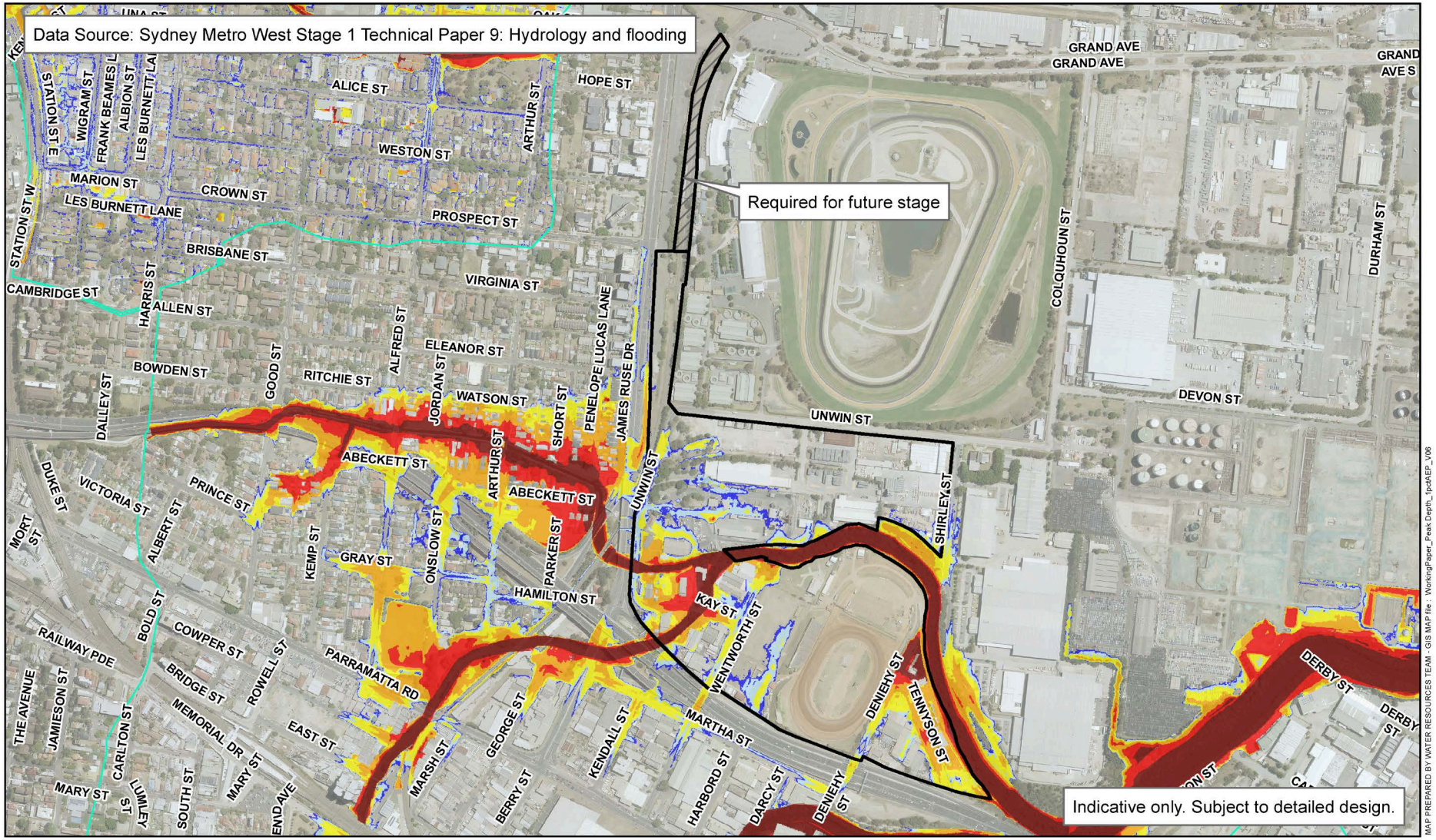


Figure A-3: Clyde stabling and maintenance facility - 1% AEP peak flood depths

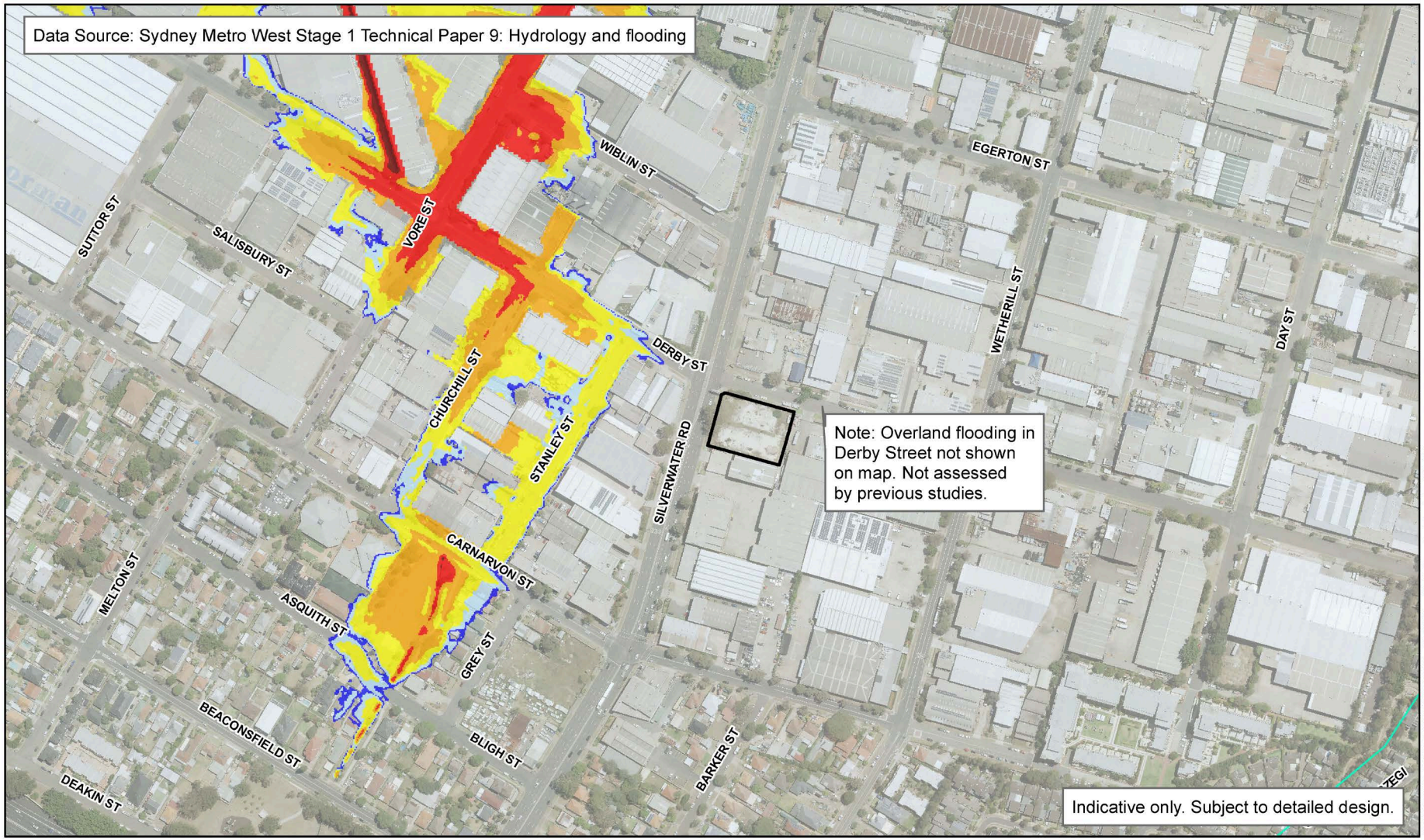


Figure A-4: Silverwater services facility - 1% AEP peak flood depths

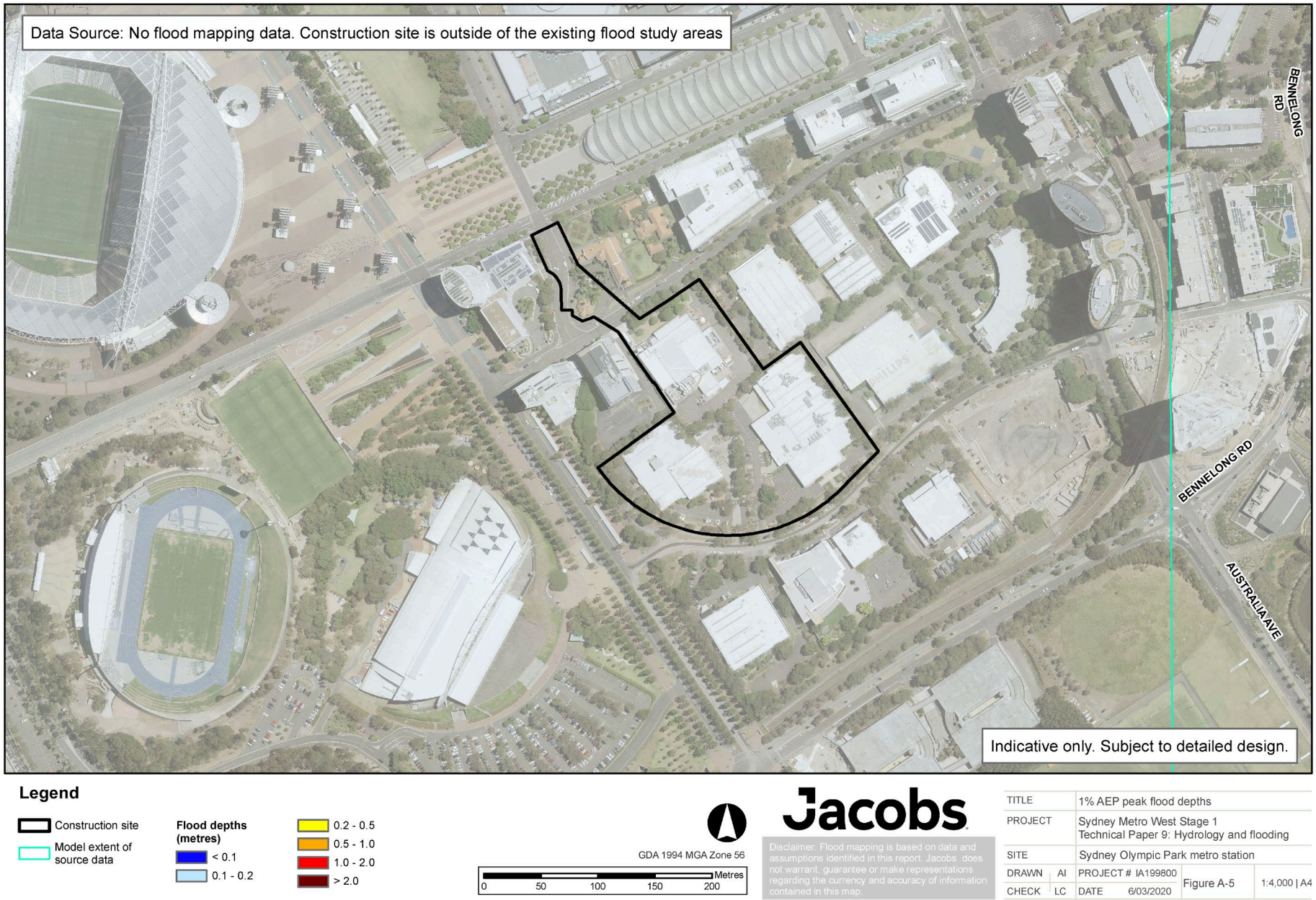


Figure A-5: Sydney Olympic Park metro station - 1% AEP peak flood depths

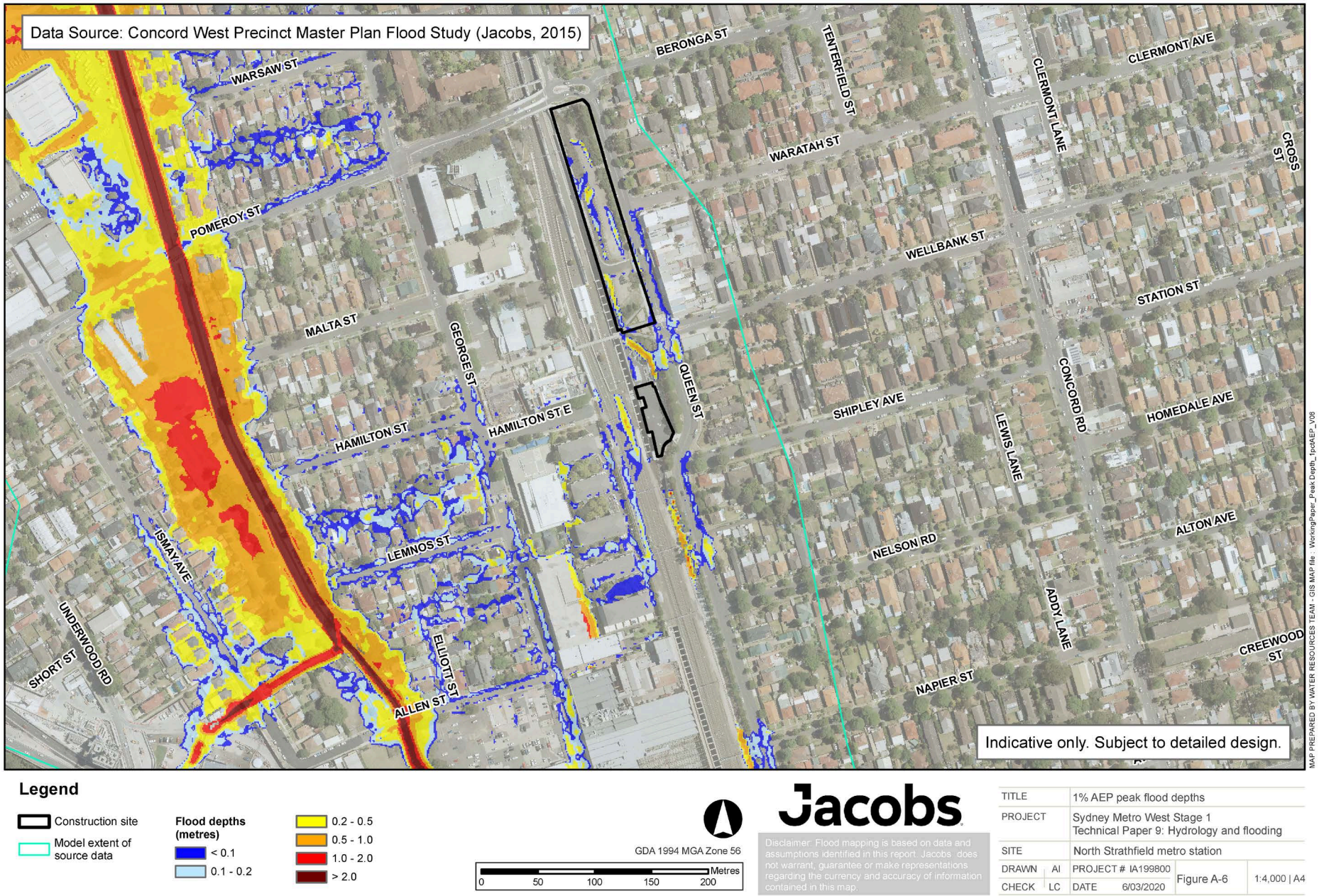


Figure A-6: North Strathfield metro station - 1% AEP peak flood depths

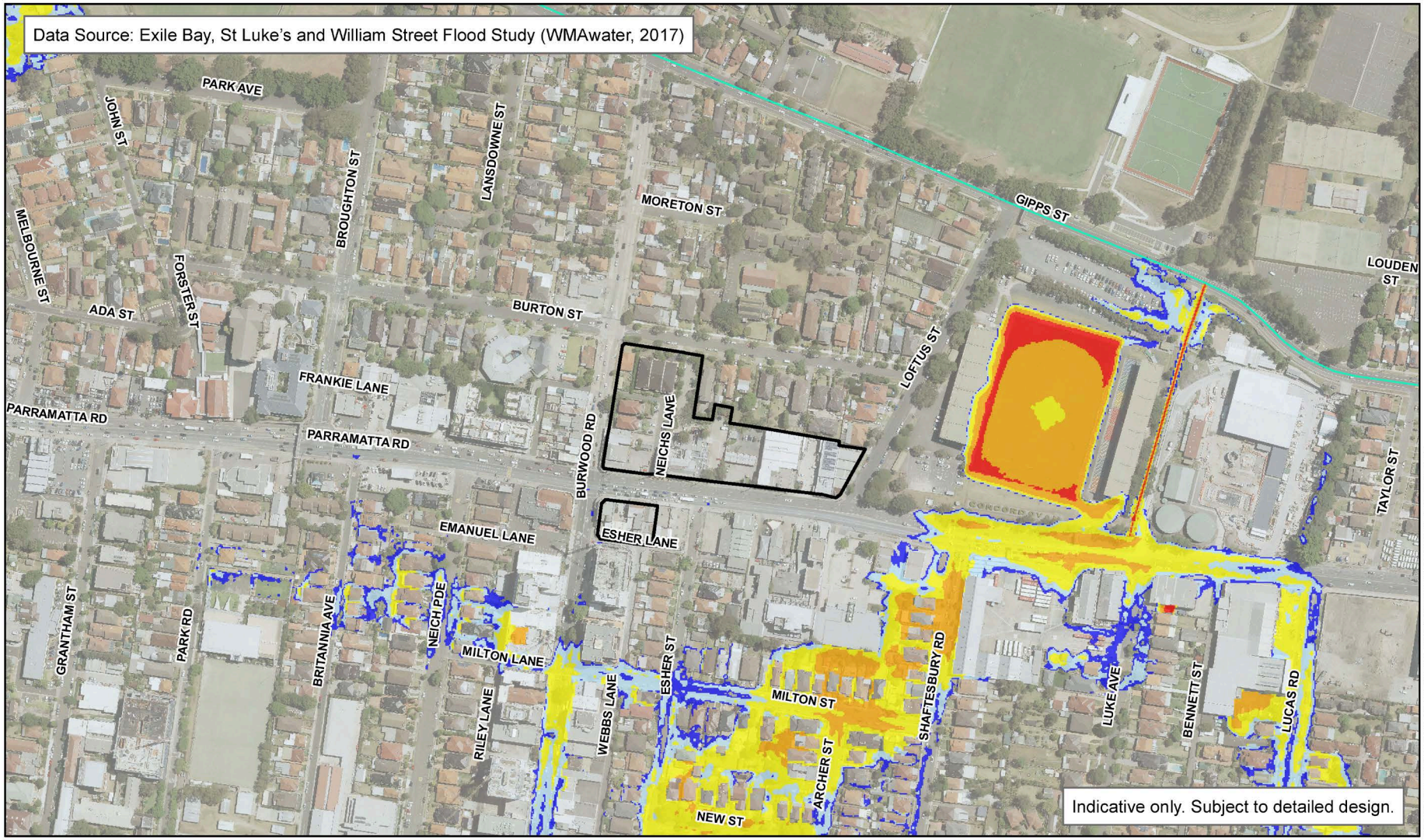


Figure A-7: Burwood North Station - 1% AEP peak flood depths

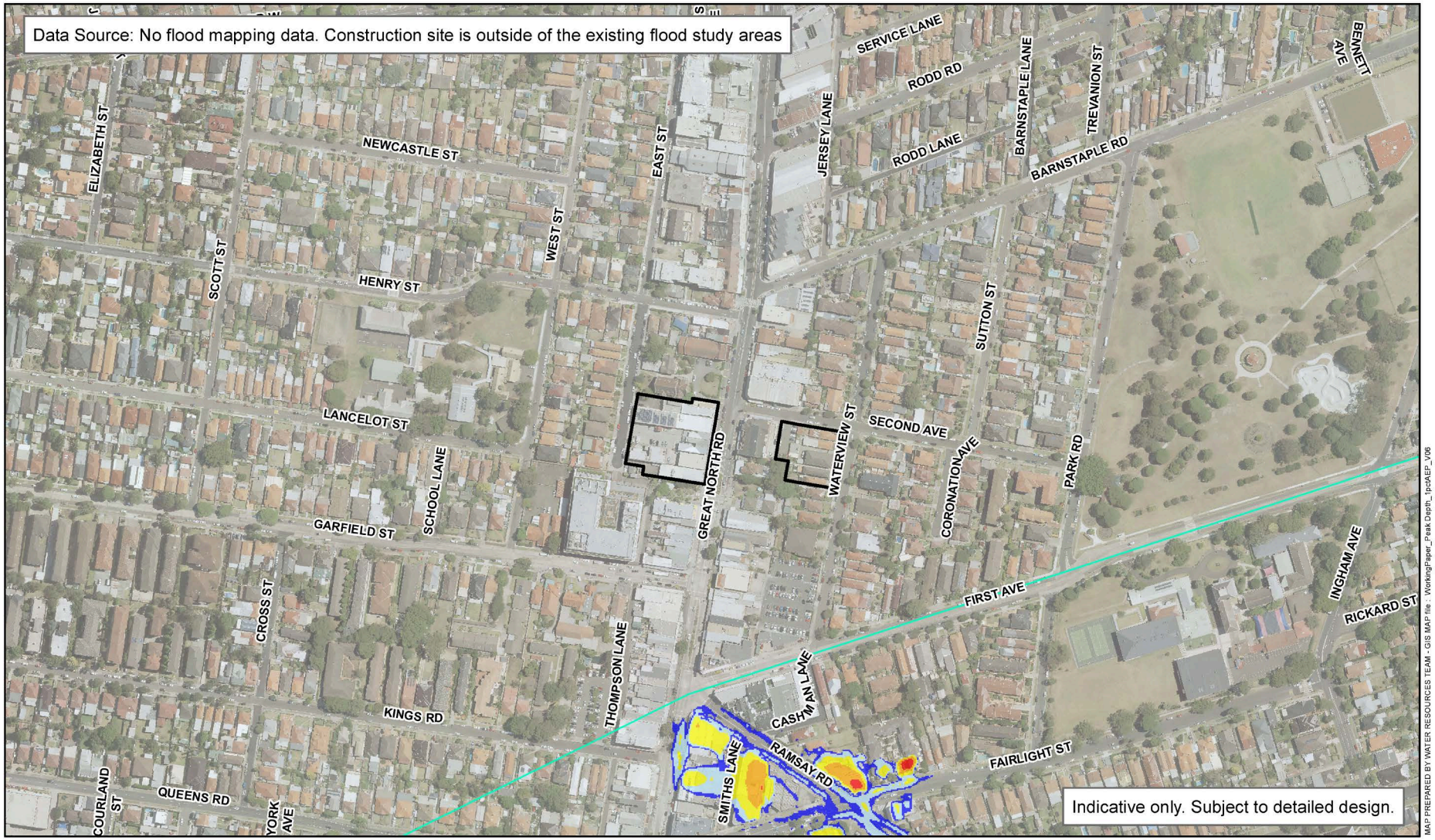
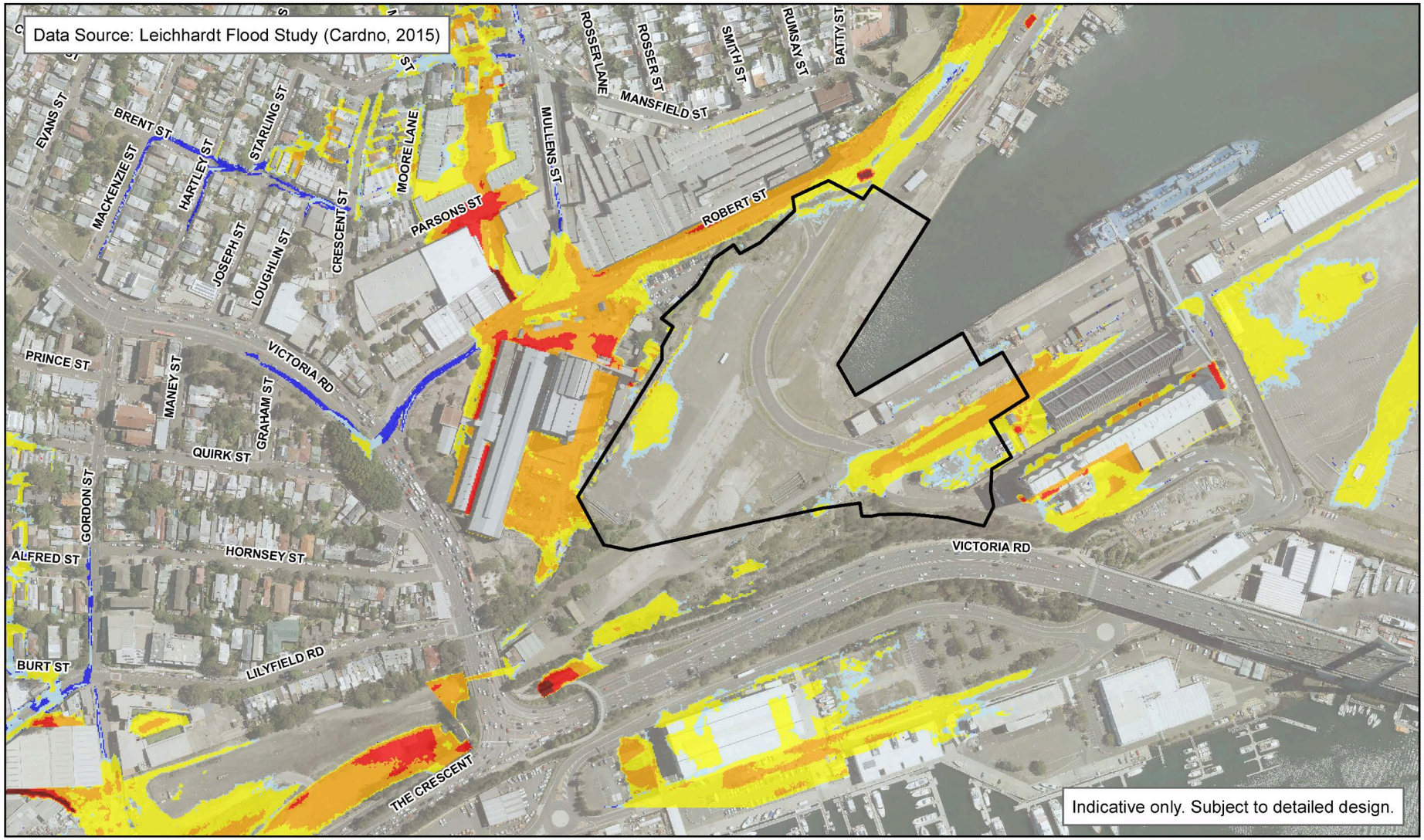


Figure A-8: Five Dock Station - 1% AEP peak flood depths



Legend

- Construction site
- Model extent of source data

Flood depths (metres)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

GDA 1994 MGA Zone 56

0 50 100 150 200 Metres

Jacobs

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

TITLE	1% AEP peak flood depths				
PROJECT	Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding				
SITE	The Bays Station				
DRAWN	AI	PROJECT #	IA199800	Figure A-9	1:4,000 | A4
CHECK	LC	DATE	6/03/2020		

Figure A-9: The Bays Station - 1% AEP peak flood depths

Figure A-10: Westmead metro station - 1% AEP flood hazard

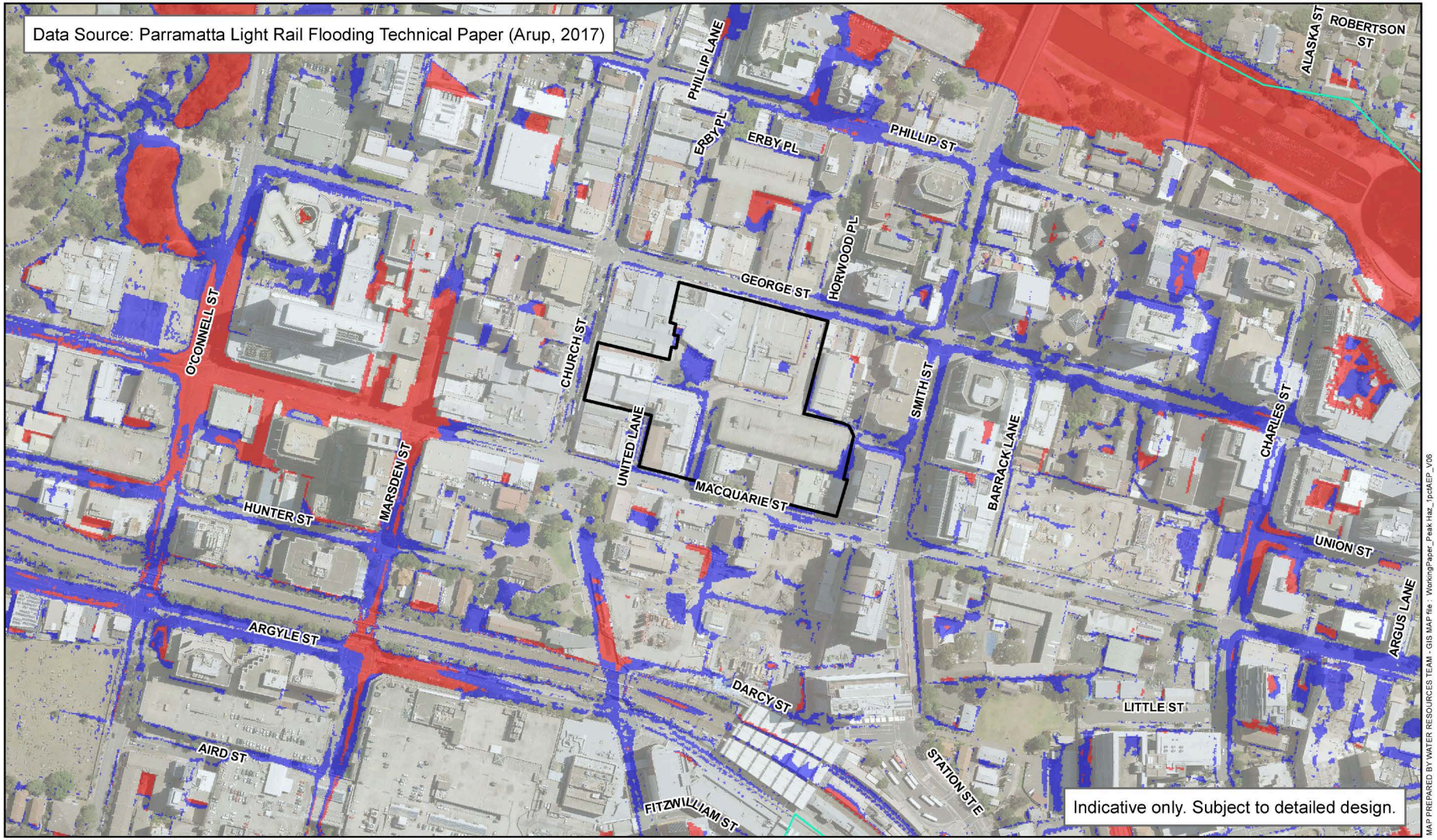


Figure A-11: Parramatta metro station - 1% AEP flood hazard

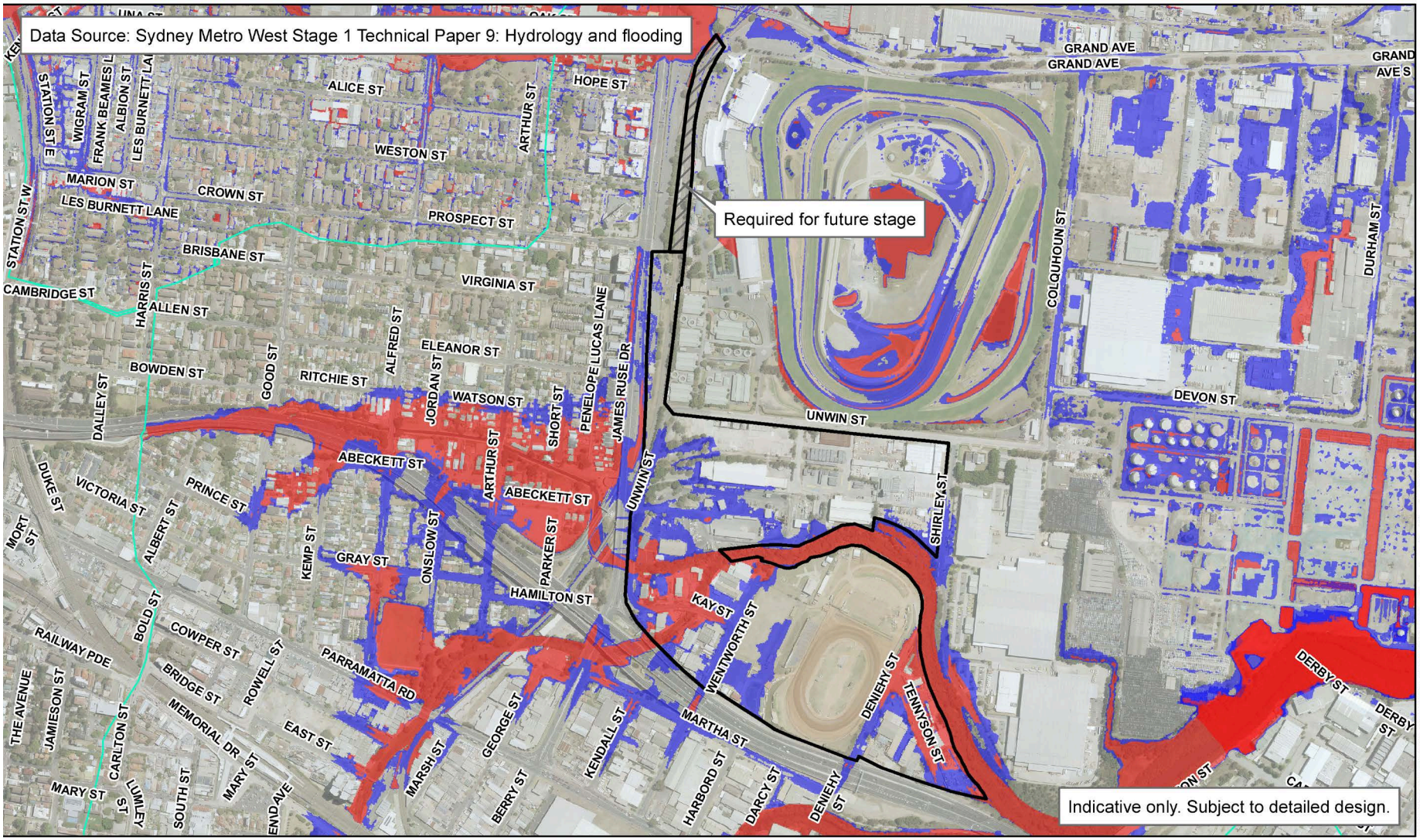


Figure A-12: Clyde stabling and maintenance facility - 1% AEP flood hazard

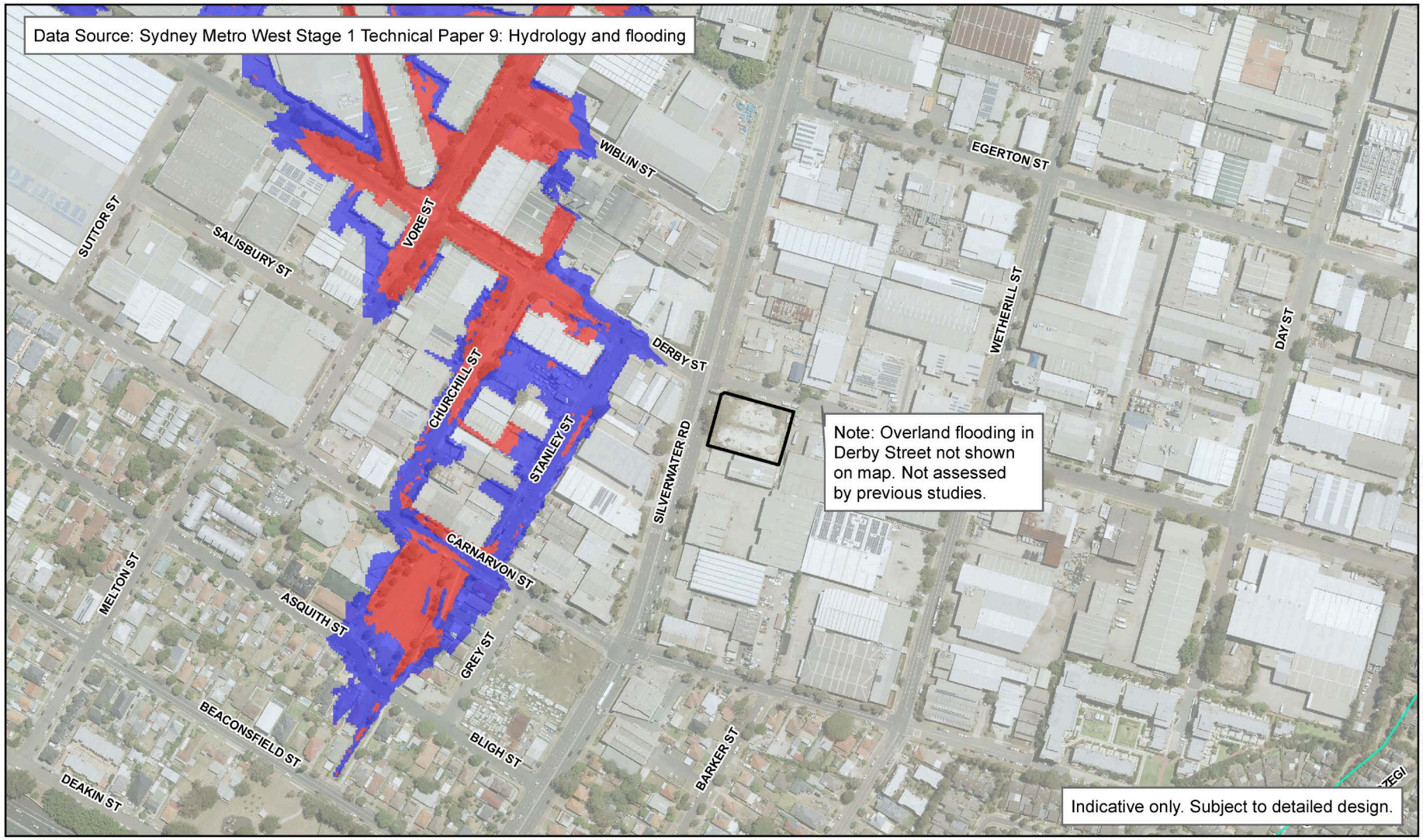


Figure A-13: Silverwater services facility - 1% AEP flood hazard

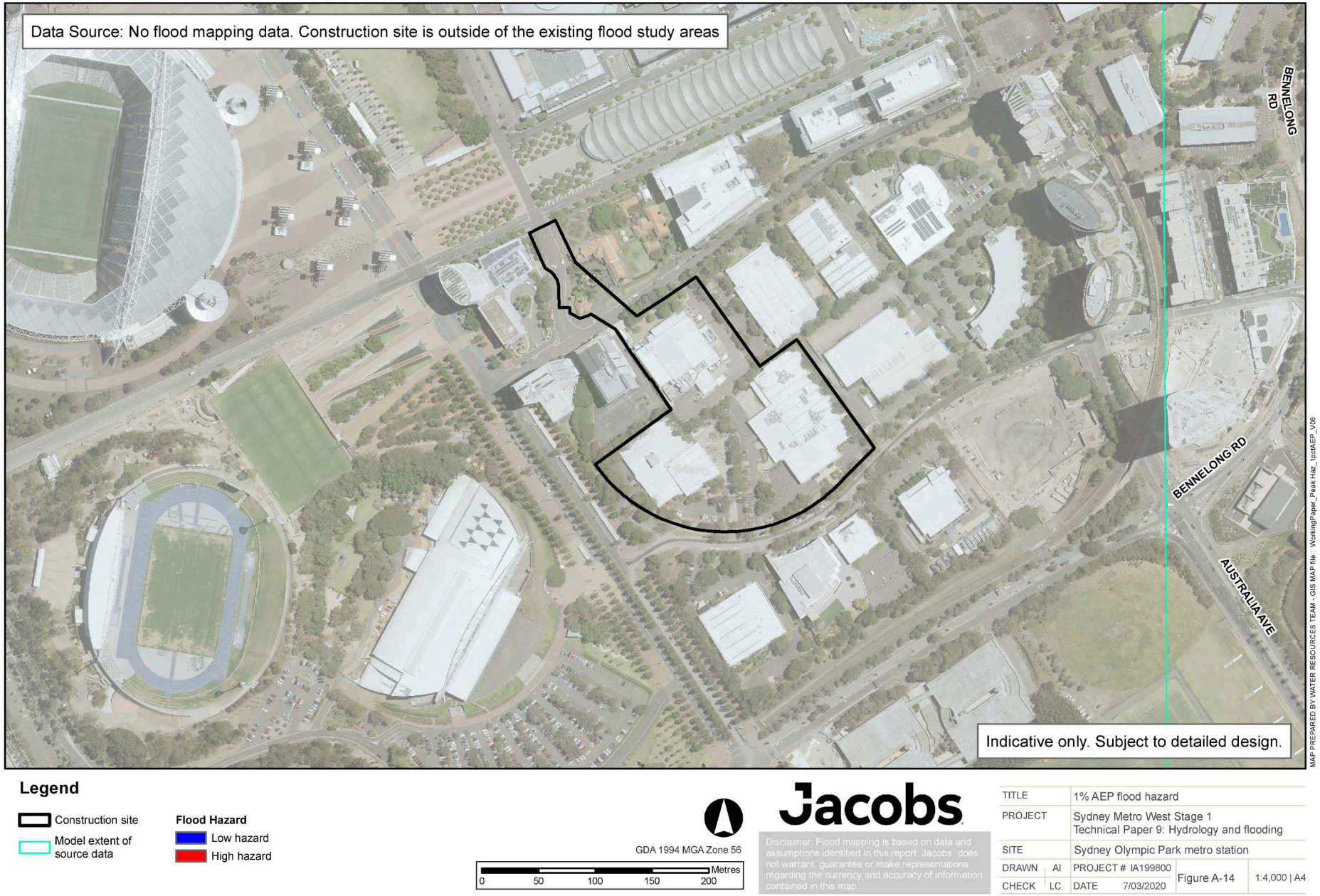


Figure A-14: Sydney Olympic Park metro station - 1% AEP flood hazard

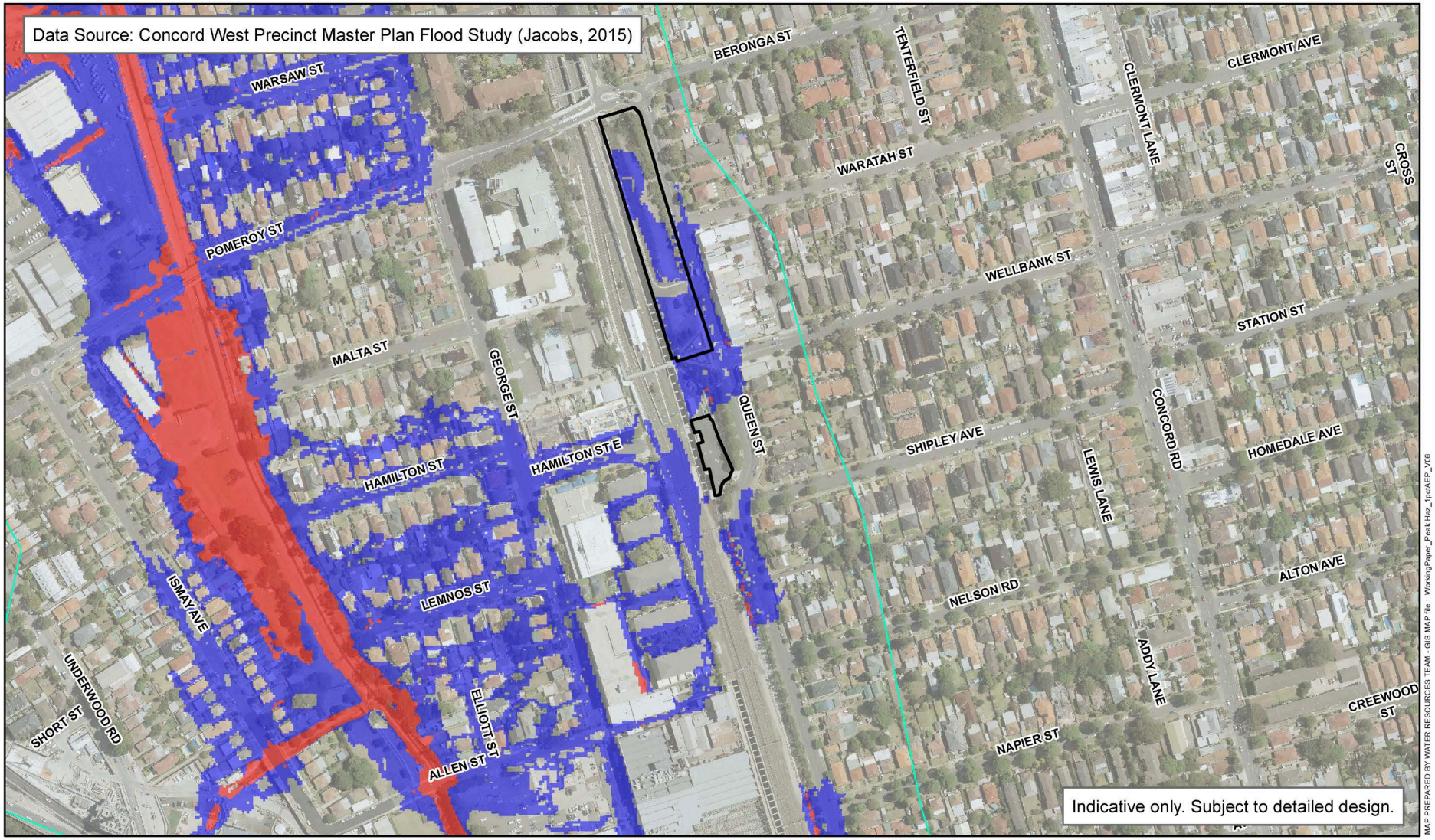


Figure A-15: North Strathfield metro station - 1% AEP flood hazard

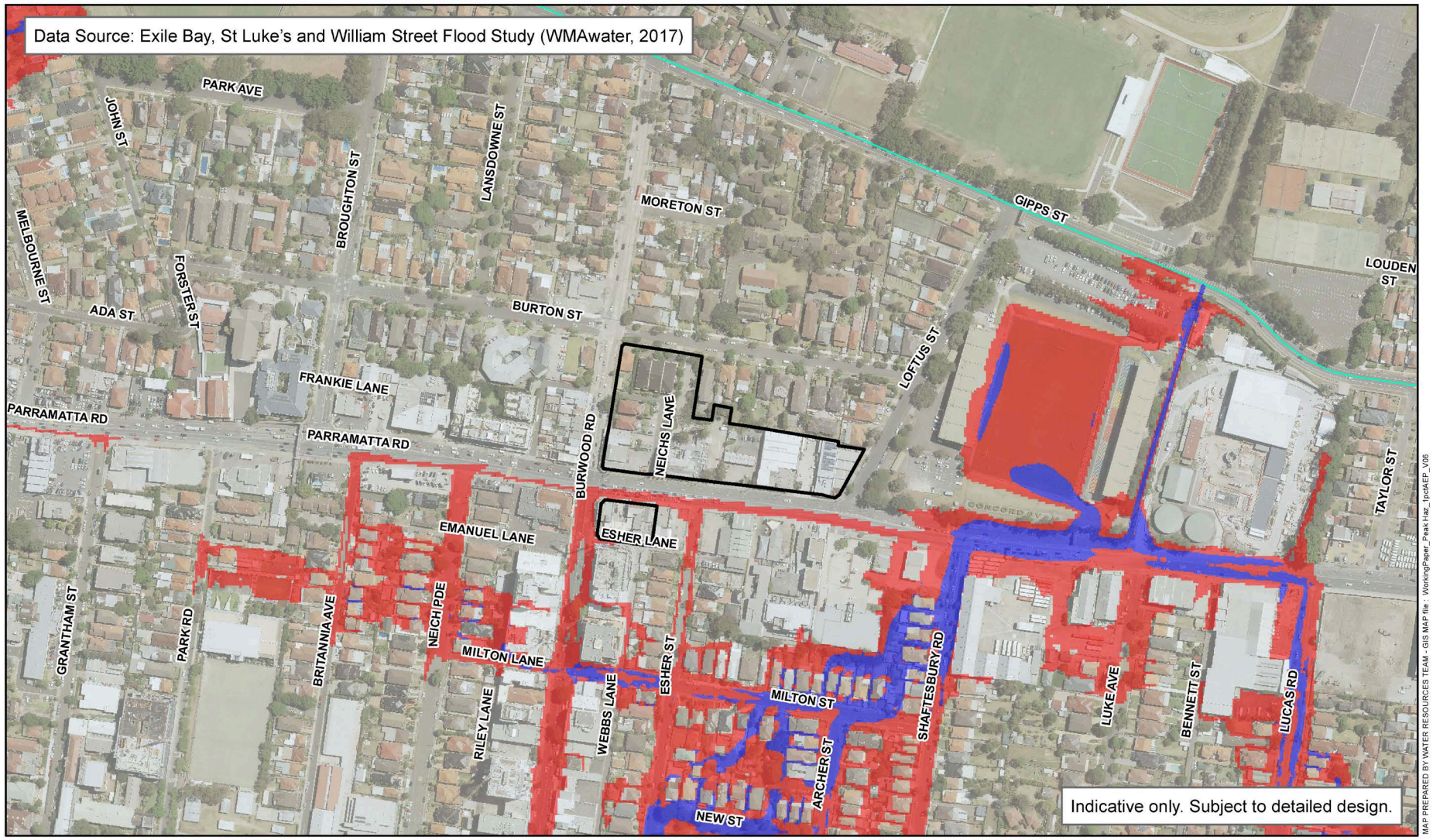


Figure A-16: Burwood North Station - 1% AEP flood hazard

Figure A-17: Five Dock Station - 1% AEP flood hazard

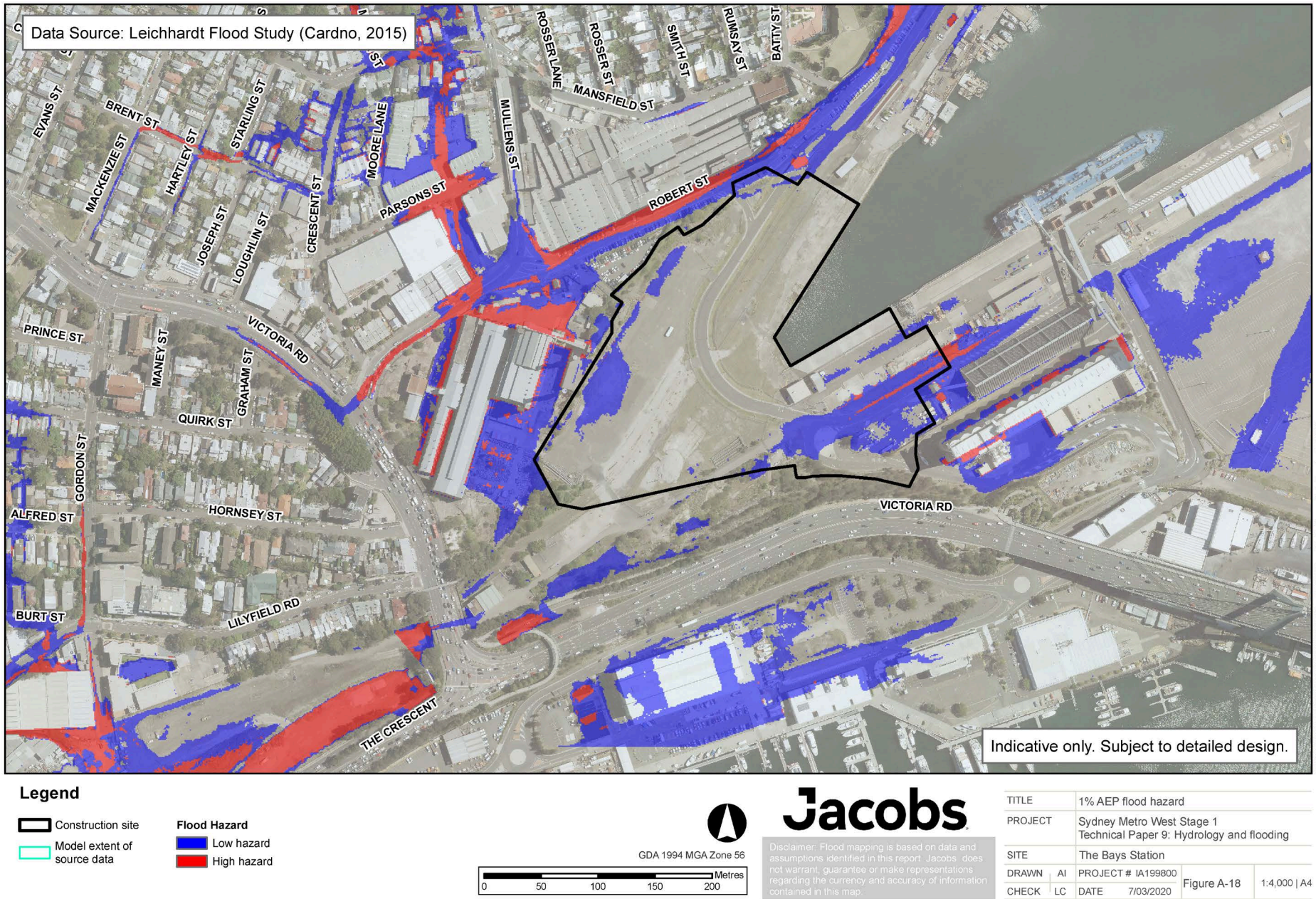


Figure A-18: The Bays Station - 1% AEP flood hazard

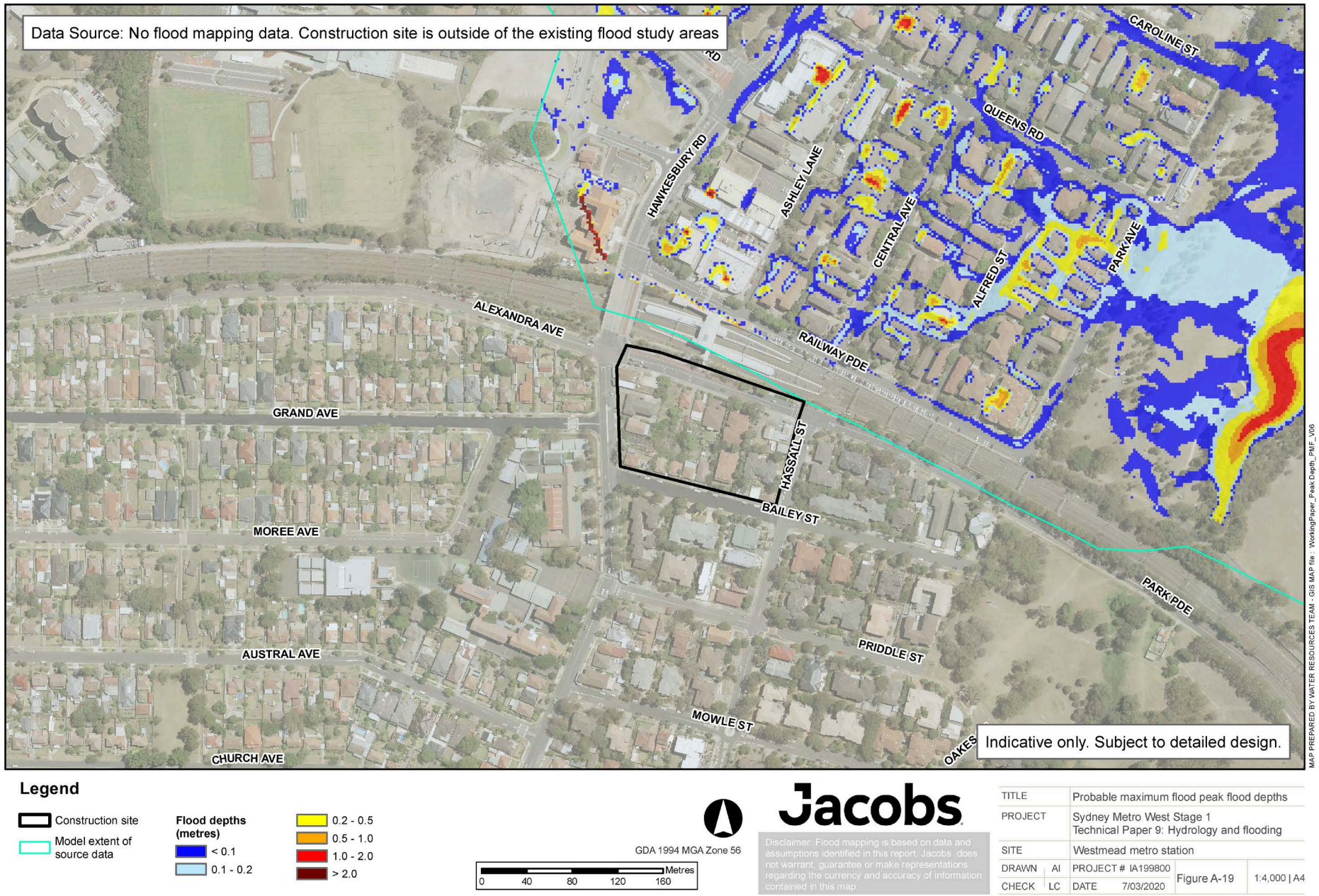


Figure A-19: Westmead metro station - Probable maximum flood peak flood depths

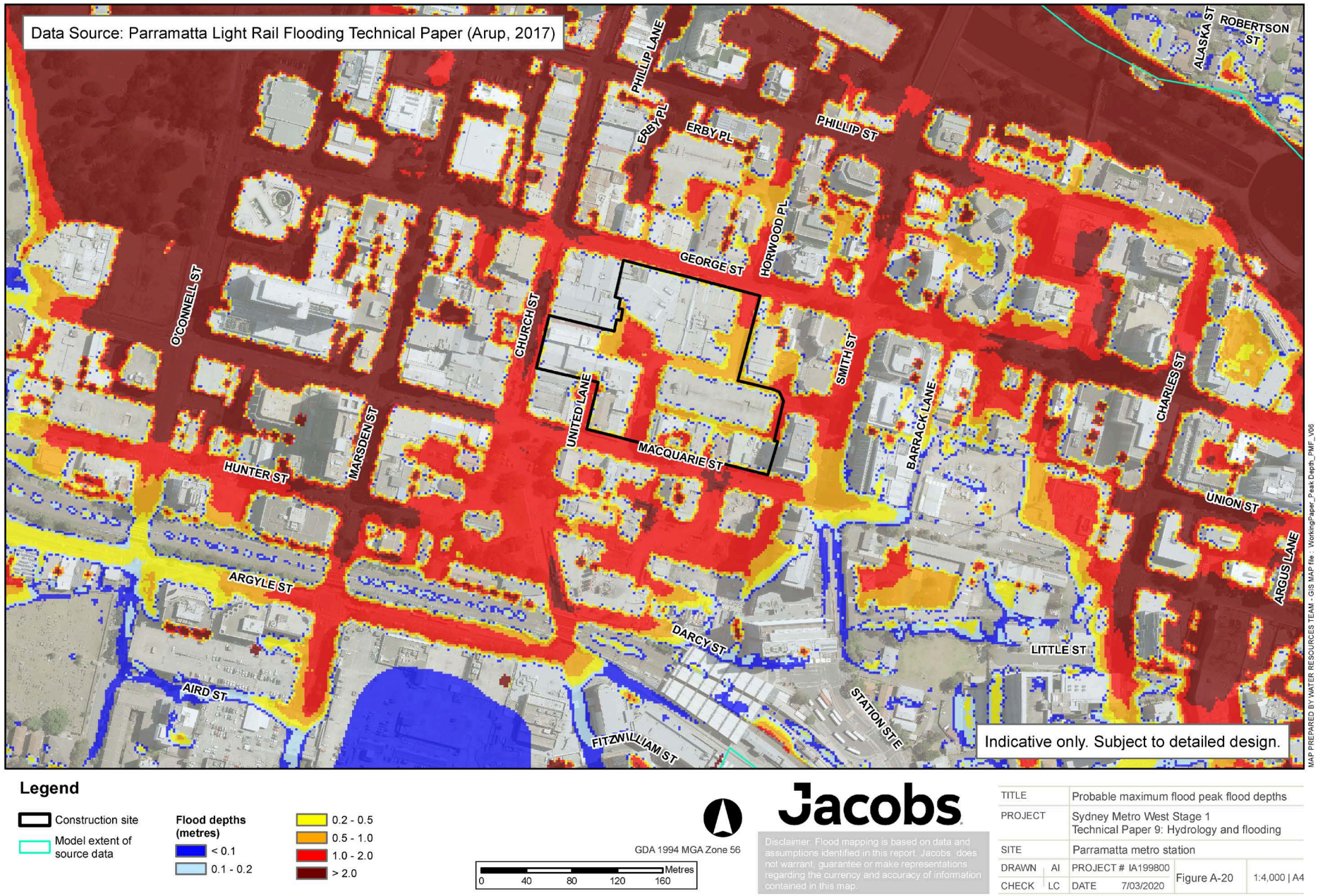


Figure A-20: Parramatta metro station - Probable maximum flood peak flood depths

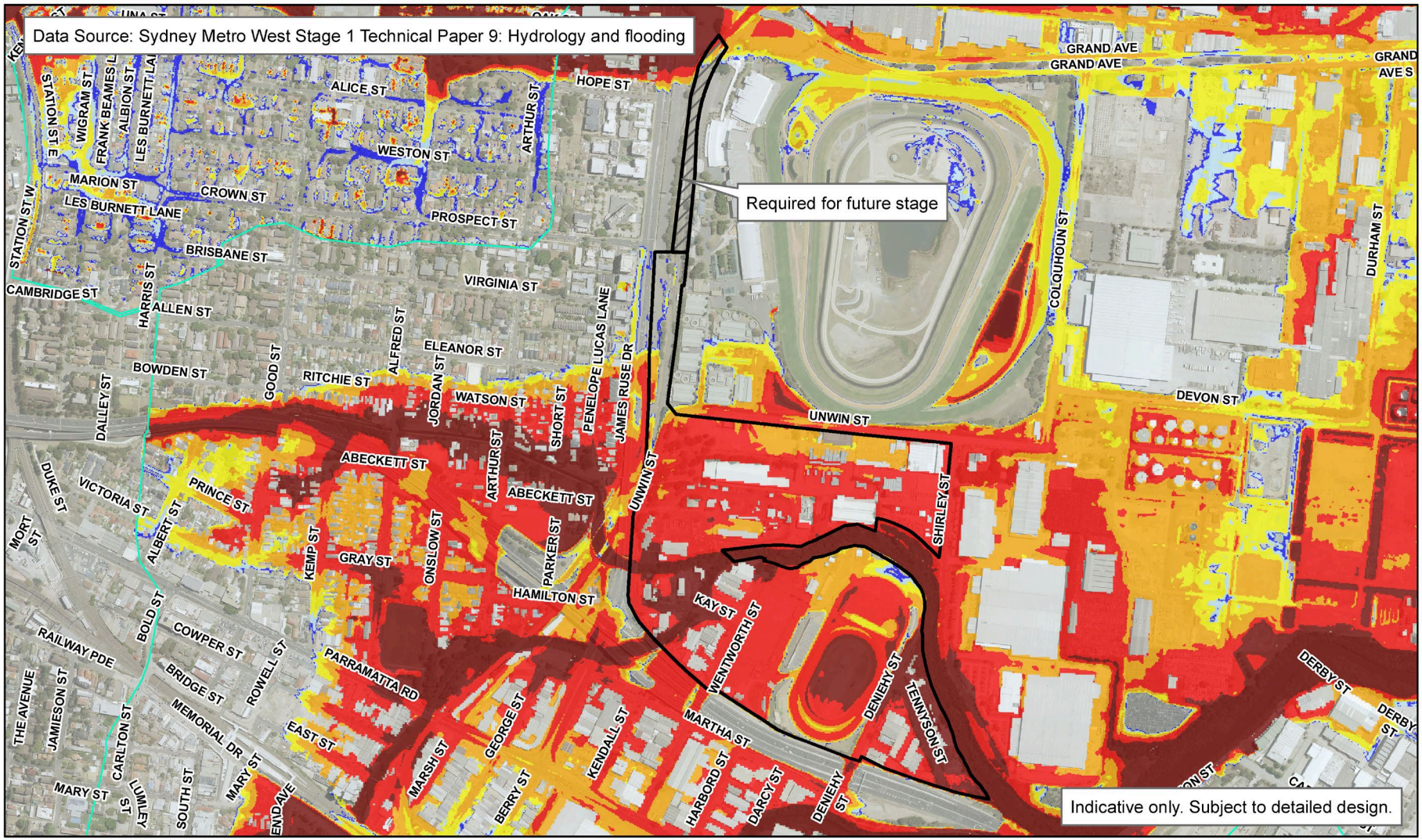


Figure A-21: Clyde stabling and maintenance facility - Probable maximum flood peak flood depths

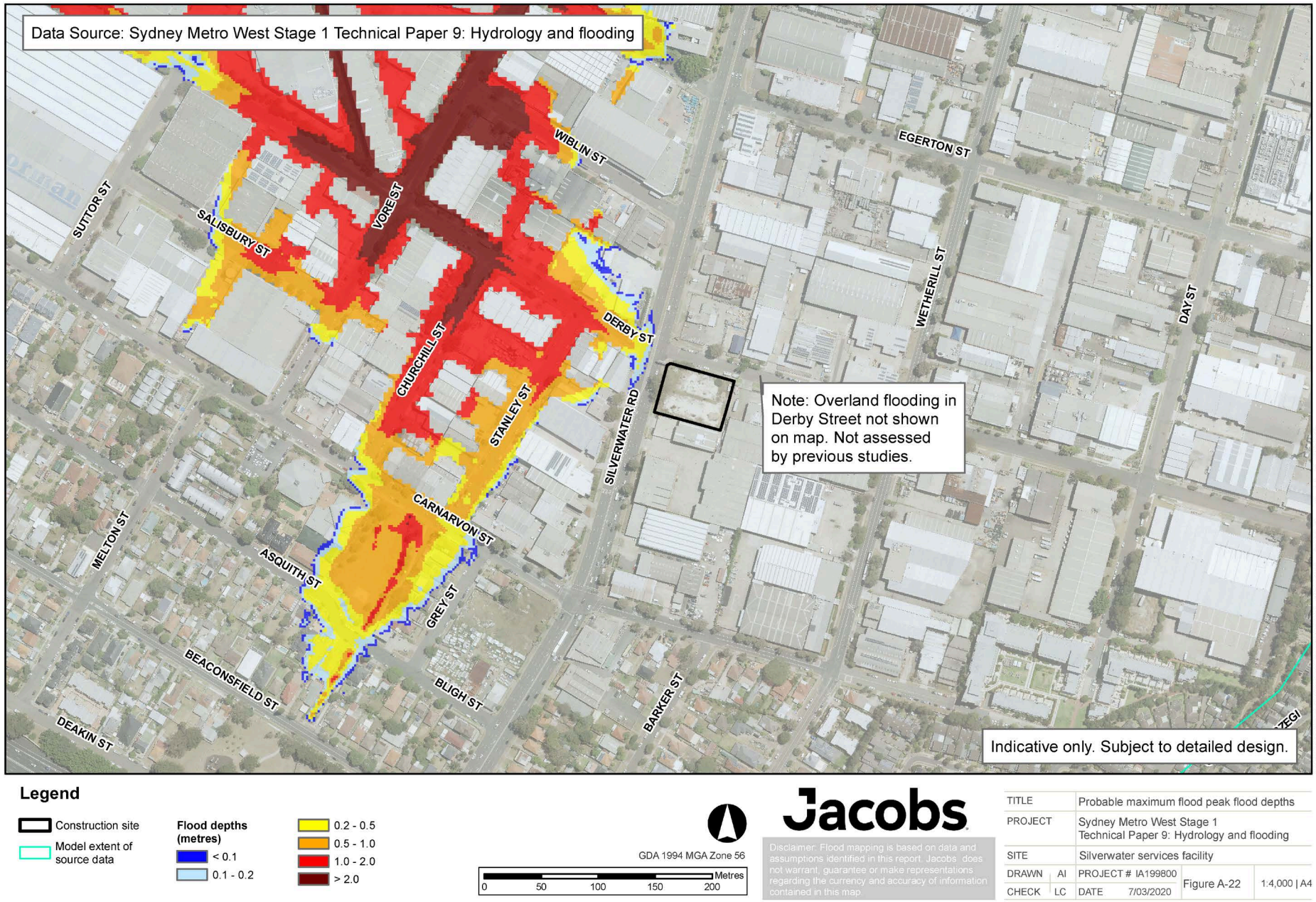


Figure A-22: Silverwater services facility - Probable maximum flood peak flood depths

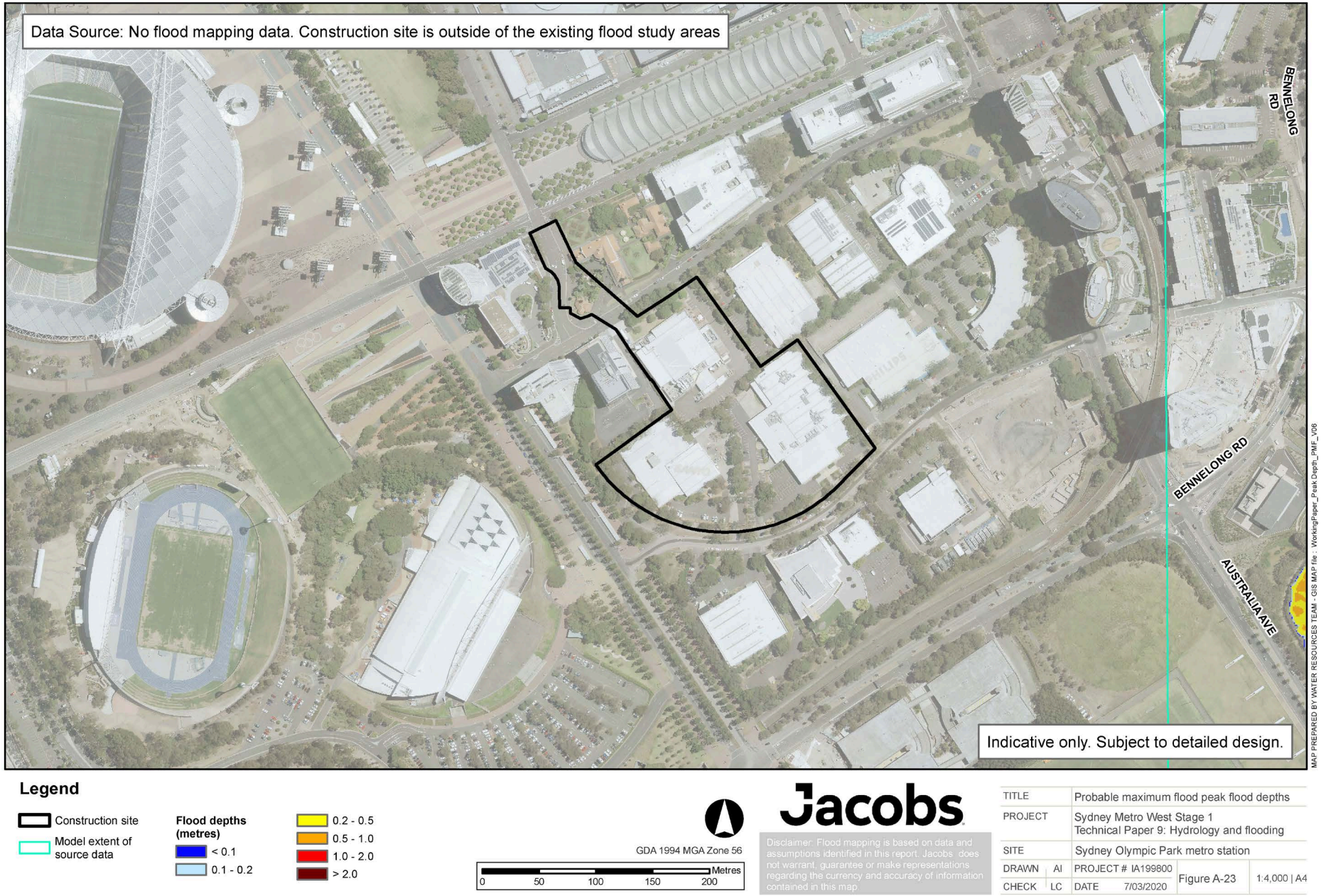


Figure A-23: Sydney Olympic Park metro station - Probable maximum flood peak flood depths

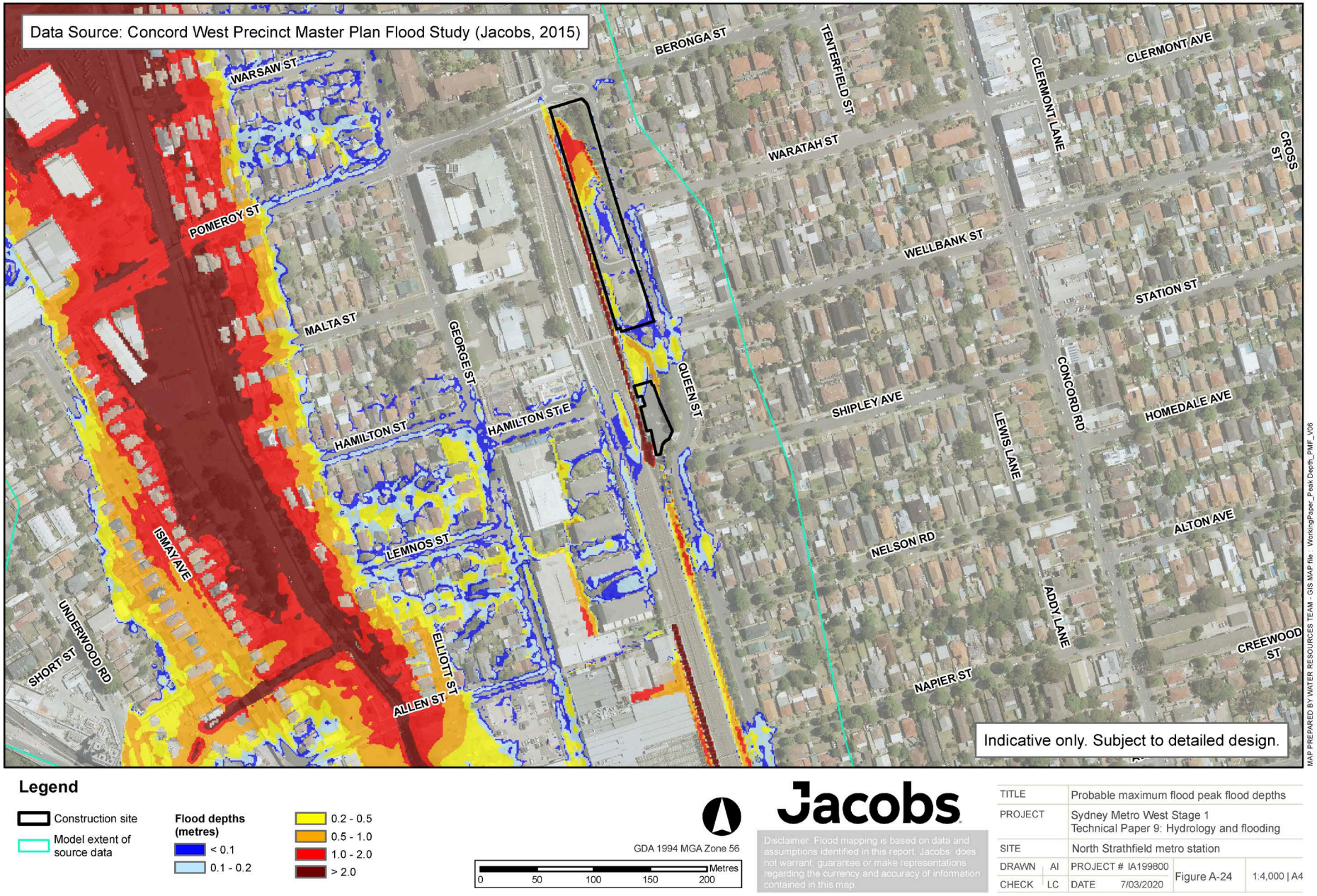


Figure A-24: North Strathfield metro station - Probable maximum flood peak flood depths

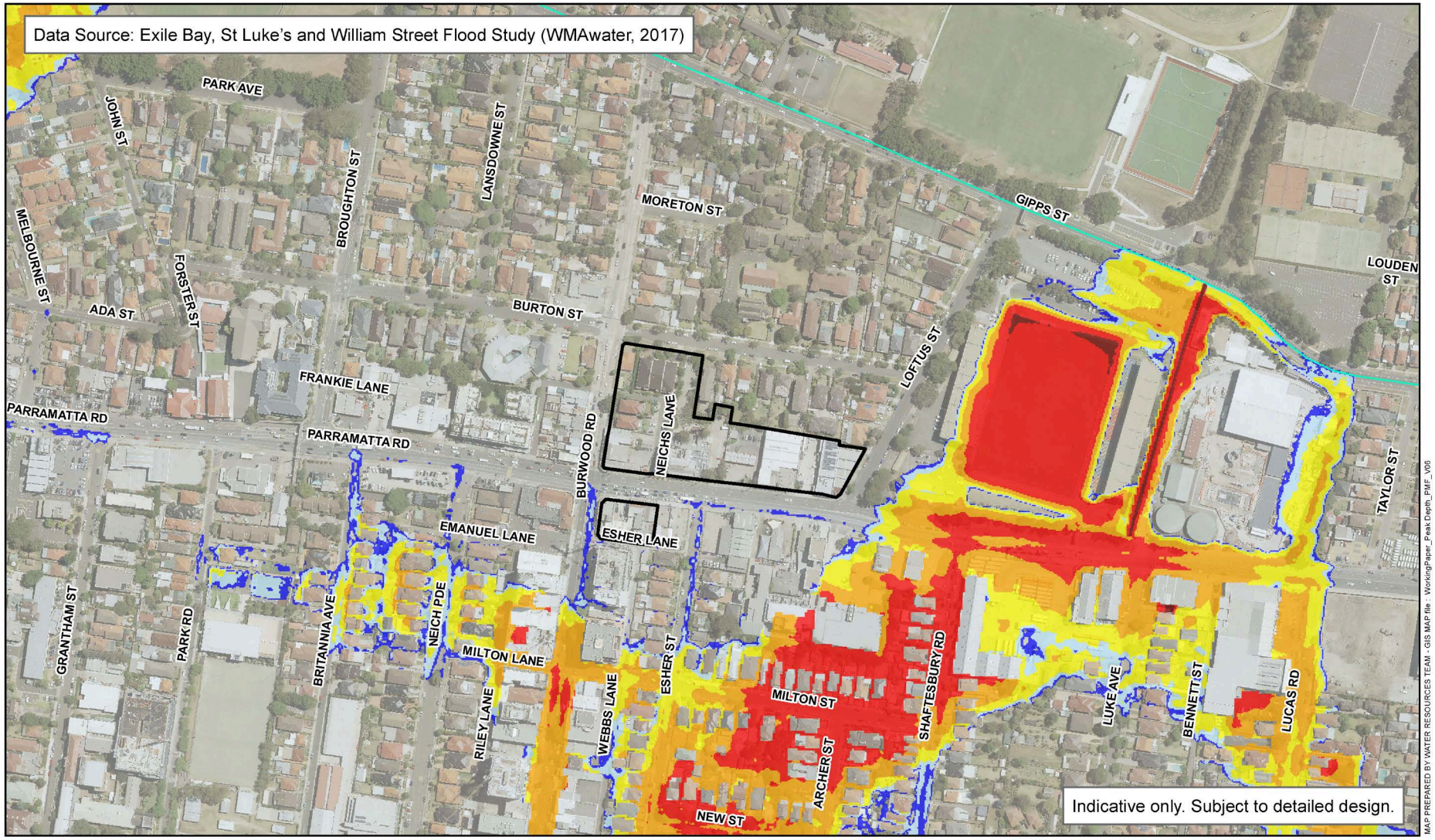


Figure A-25: Burwood North Station - Probable maximum flood peak flood depths

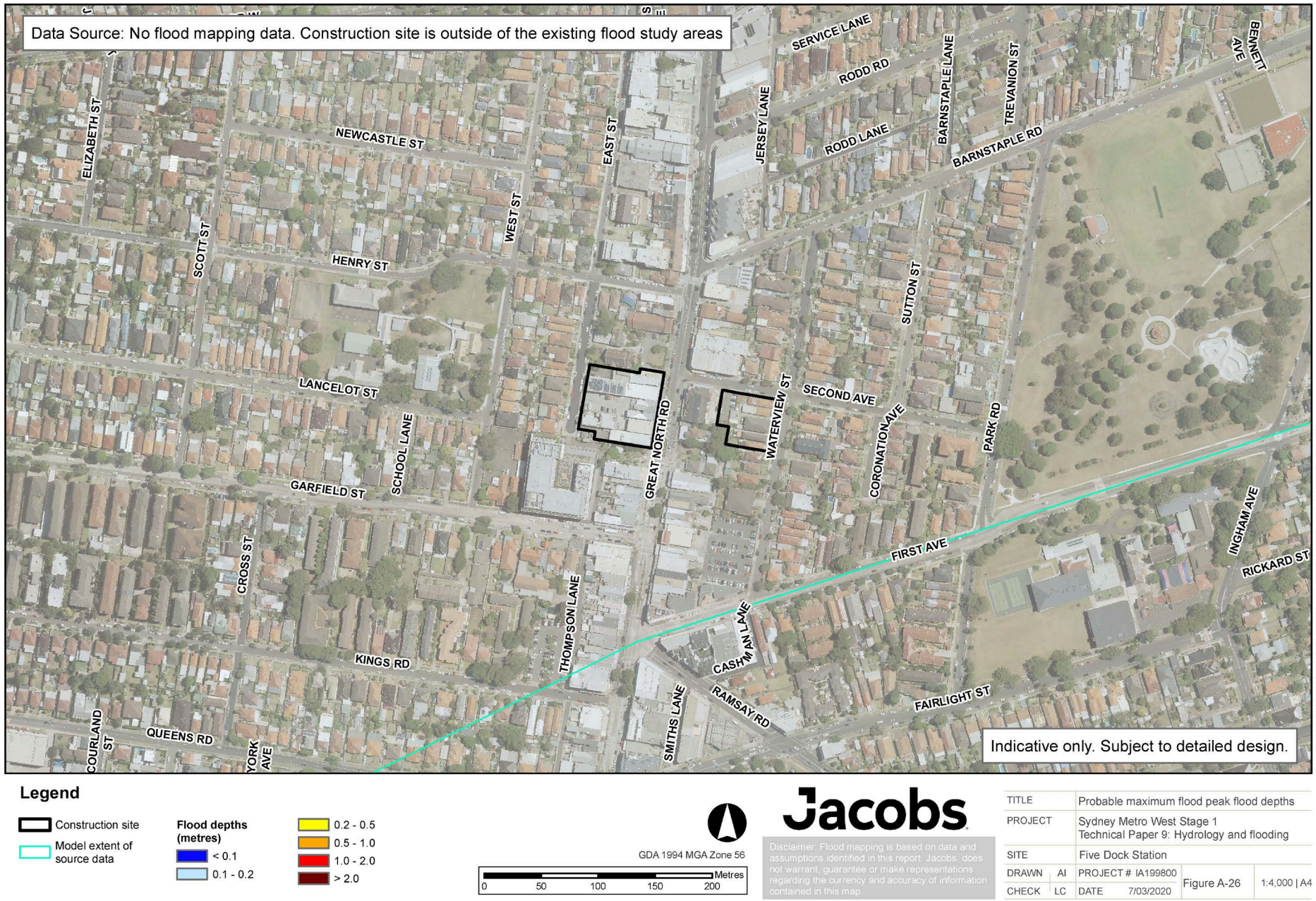


Figure A-26: Five Dock Station - Probable maximum flood peak flood depths

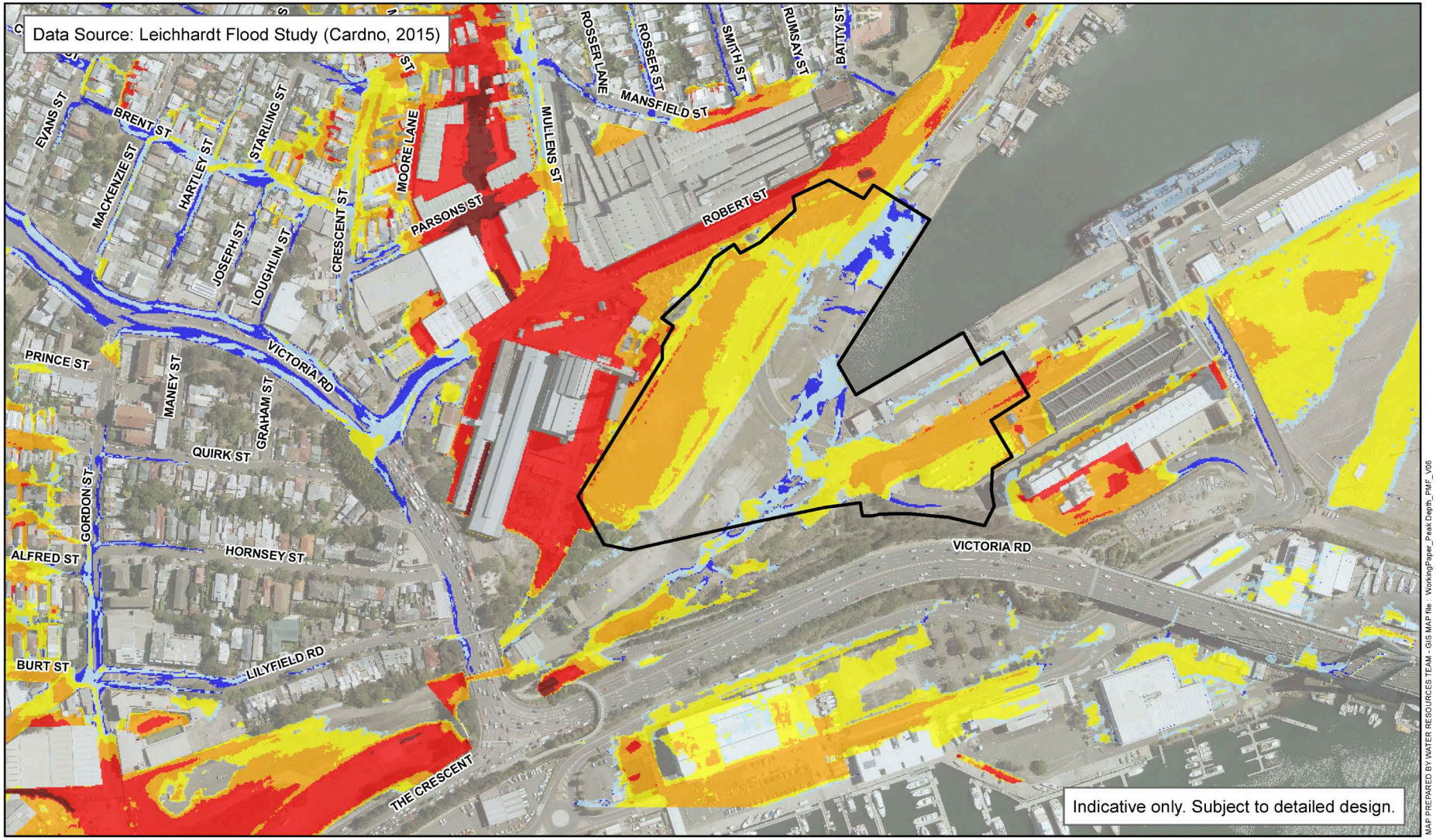


Figure A-27: The Bays Station - Probable maximum flood peak flood depths

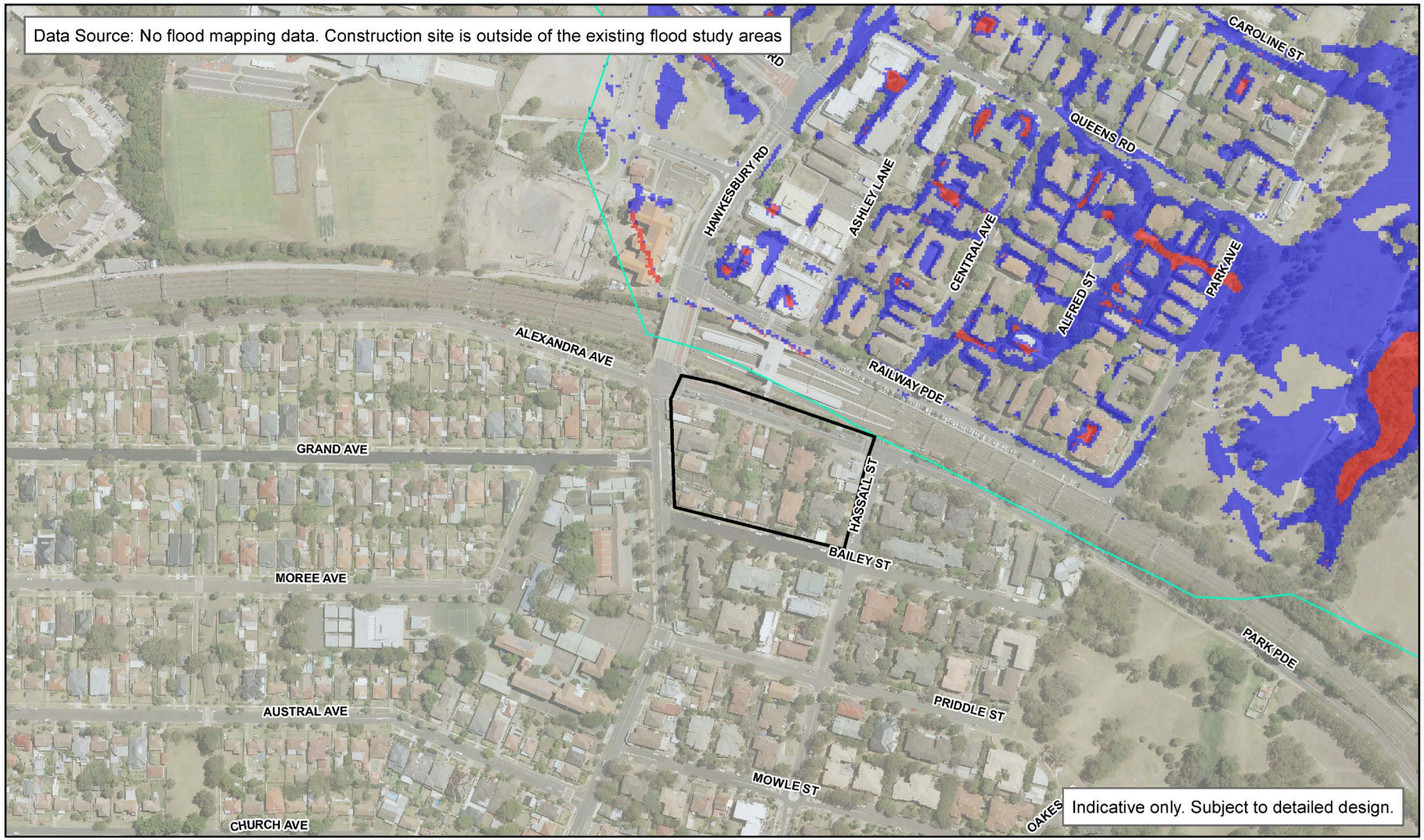


Figure A-28: Westmead metro station - Probable maximum flood hazard

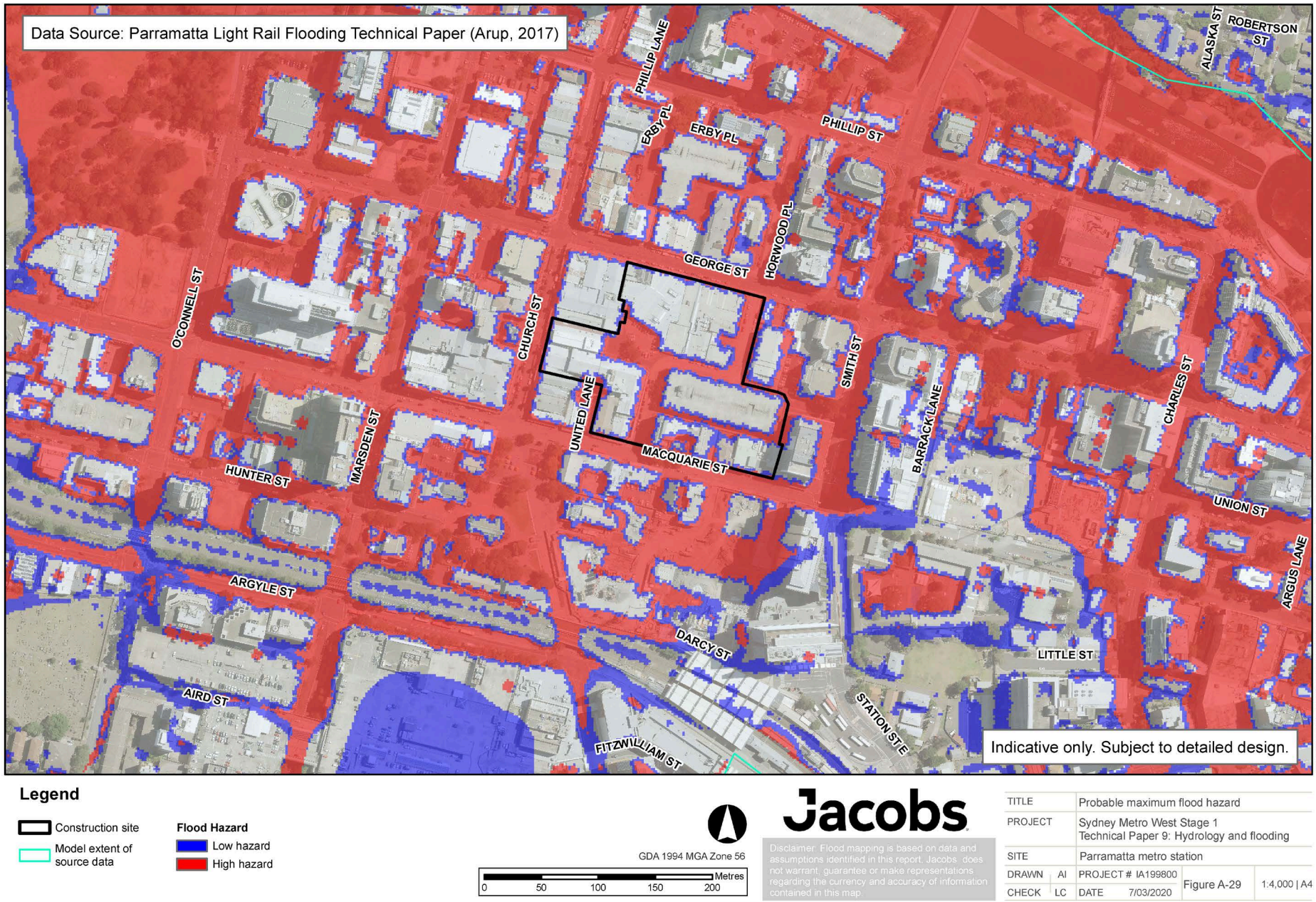


Figure A-29: Parramatta metro station - Probable maximum flood hazard

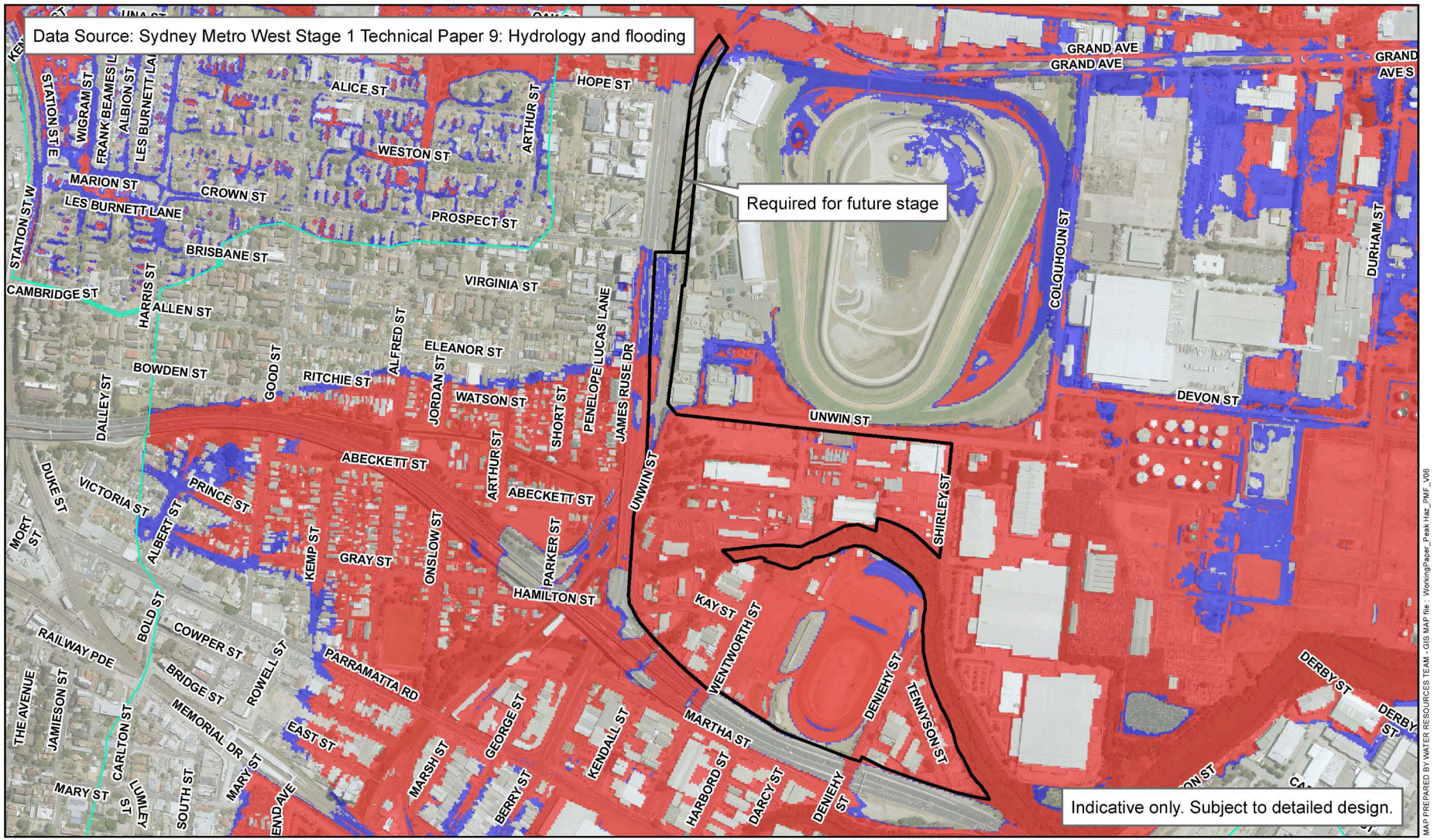


Figure A-30: Clyde stabling and maintenance facility - Probable maximum flood hazard

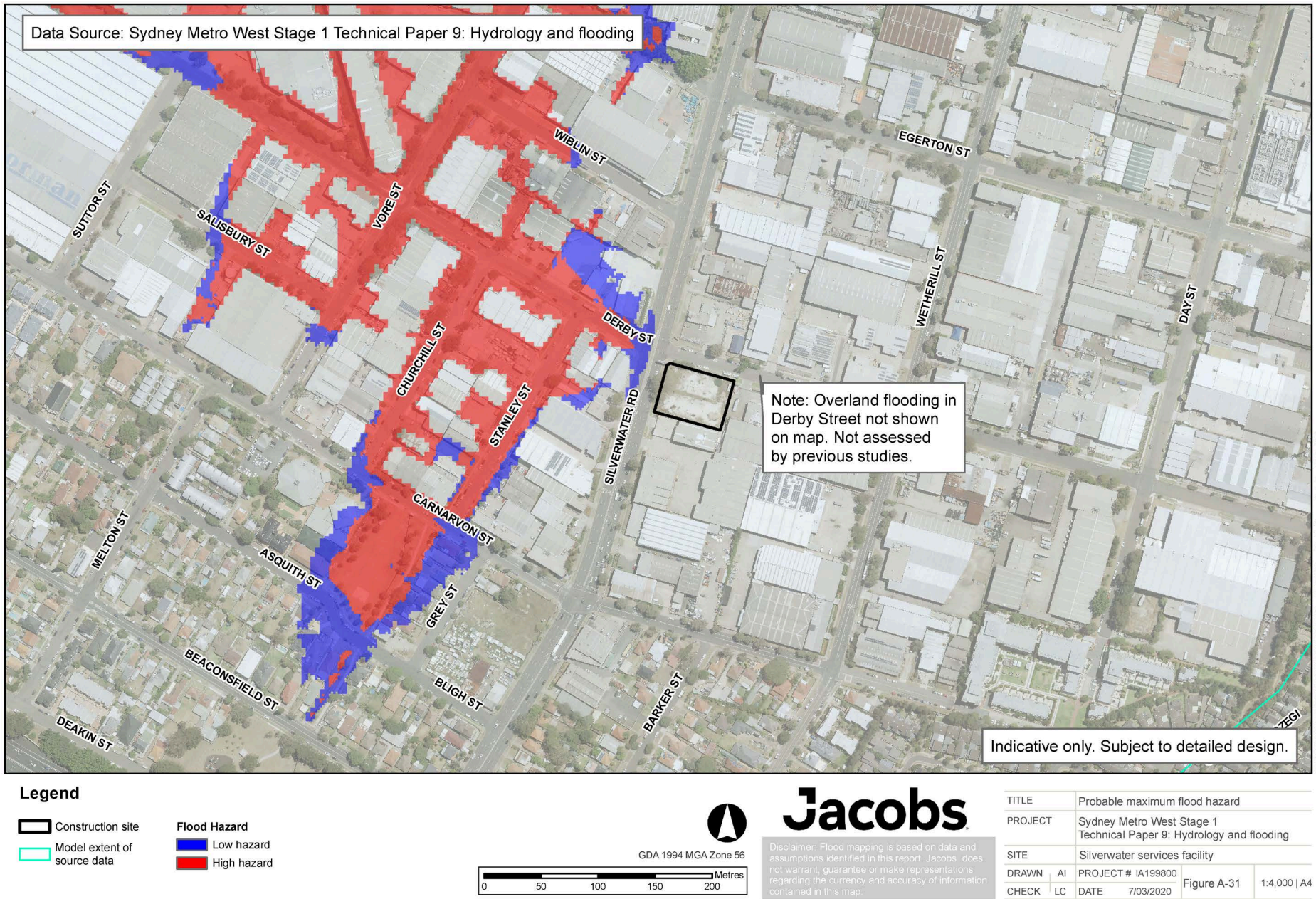


Figure A-31: Silverwater services facility - Probable maximum flood hazard

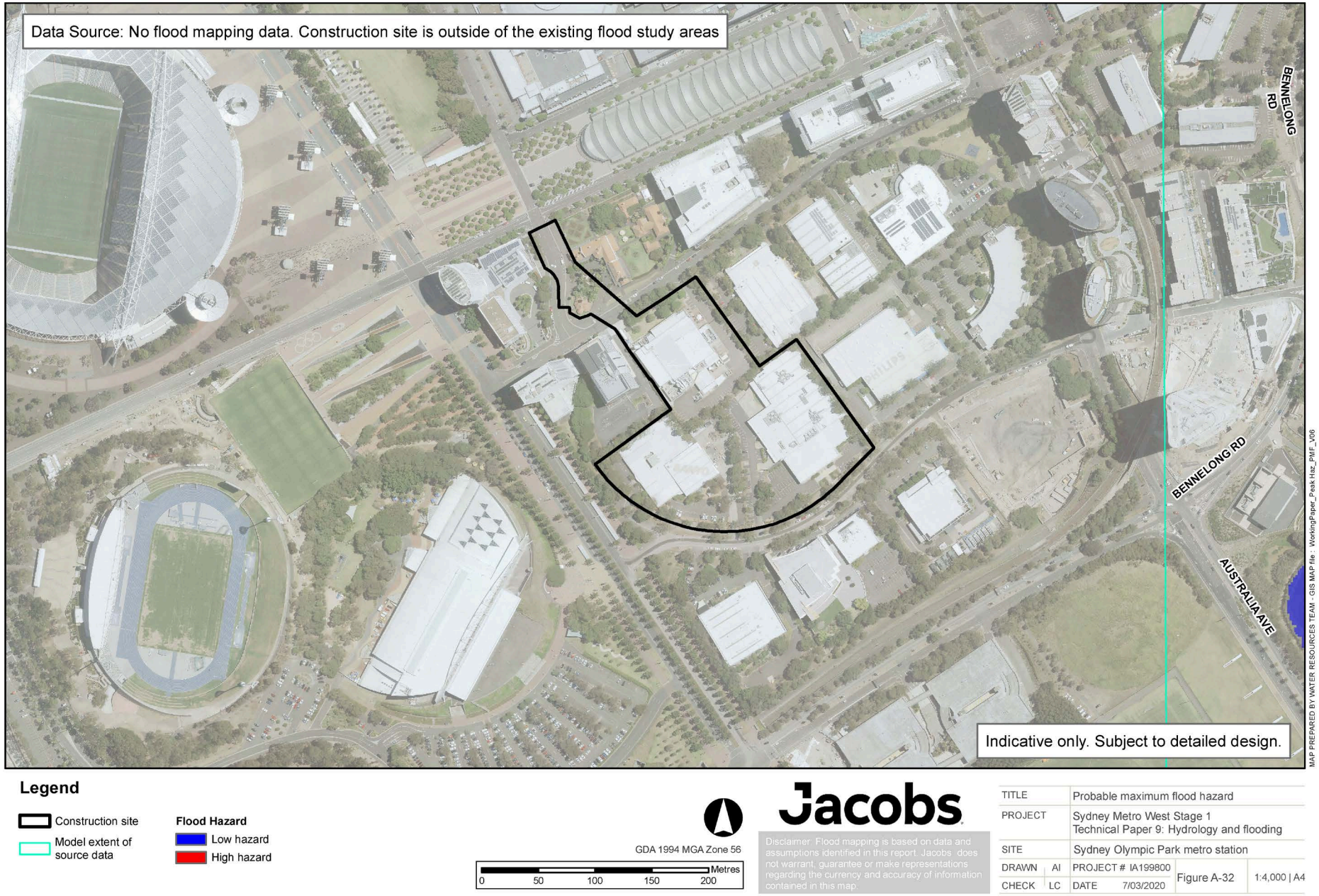


Figure A-32: Sydney Olympic Park metro station - Probable maximum flood hazard

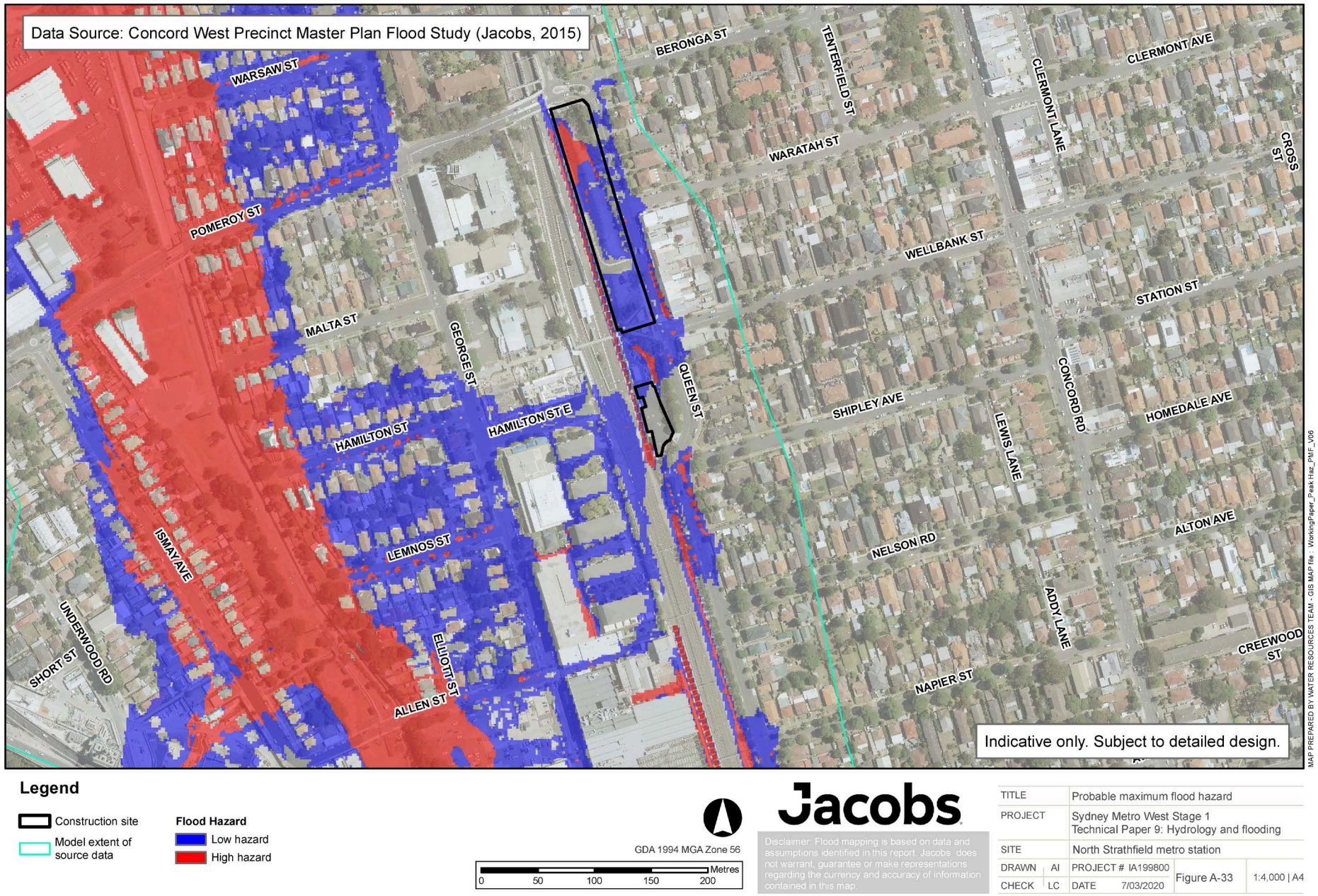


Figure A-33: North Strathfield metro station - Probable maximum flood hazard

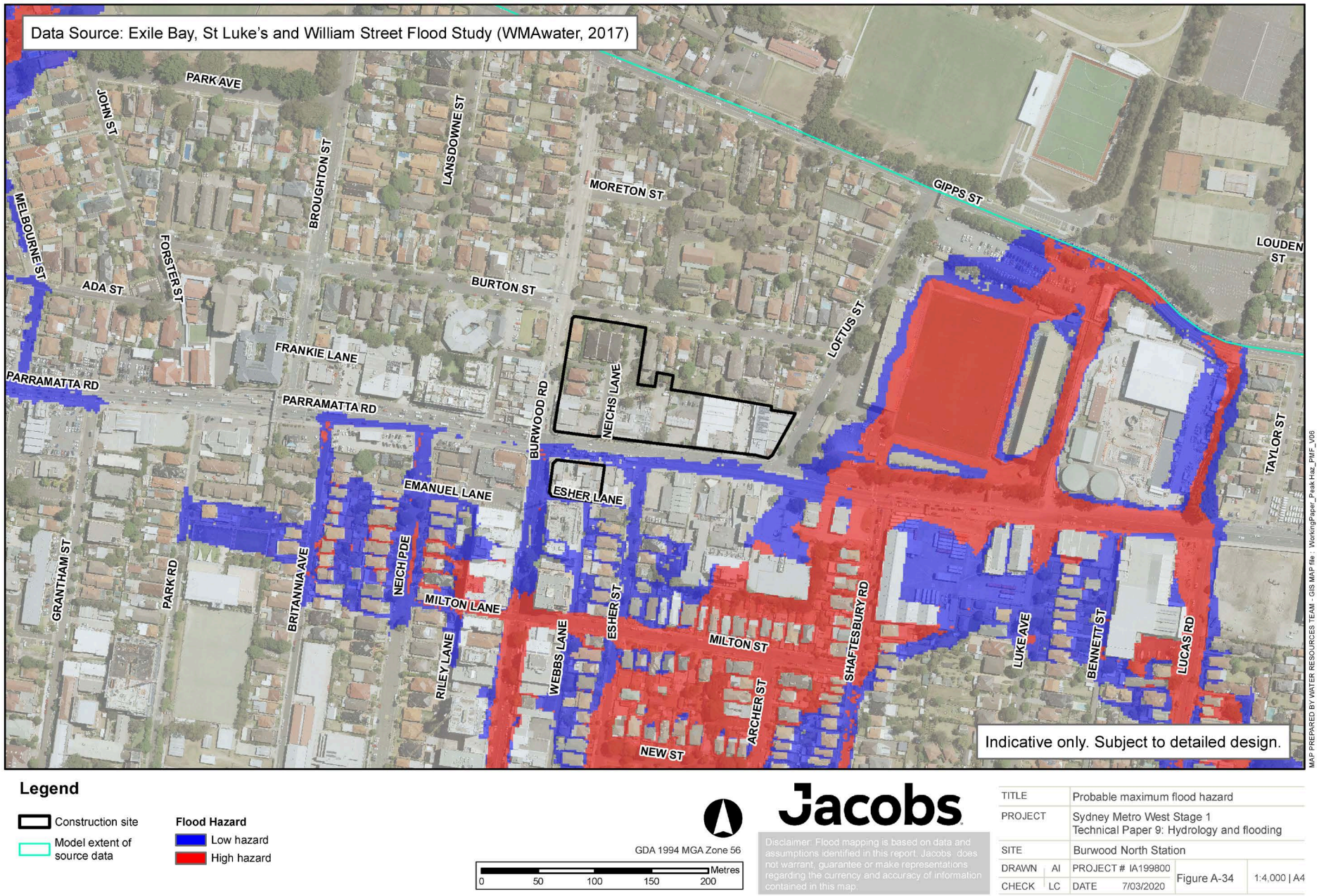


Figure A-34: Burwood North Station - Probable maximum flood hazard

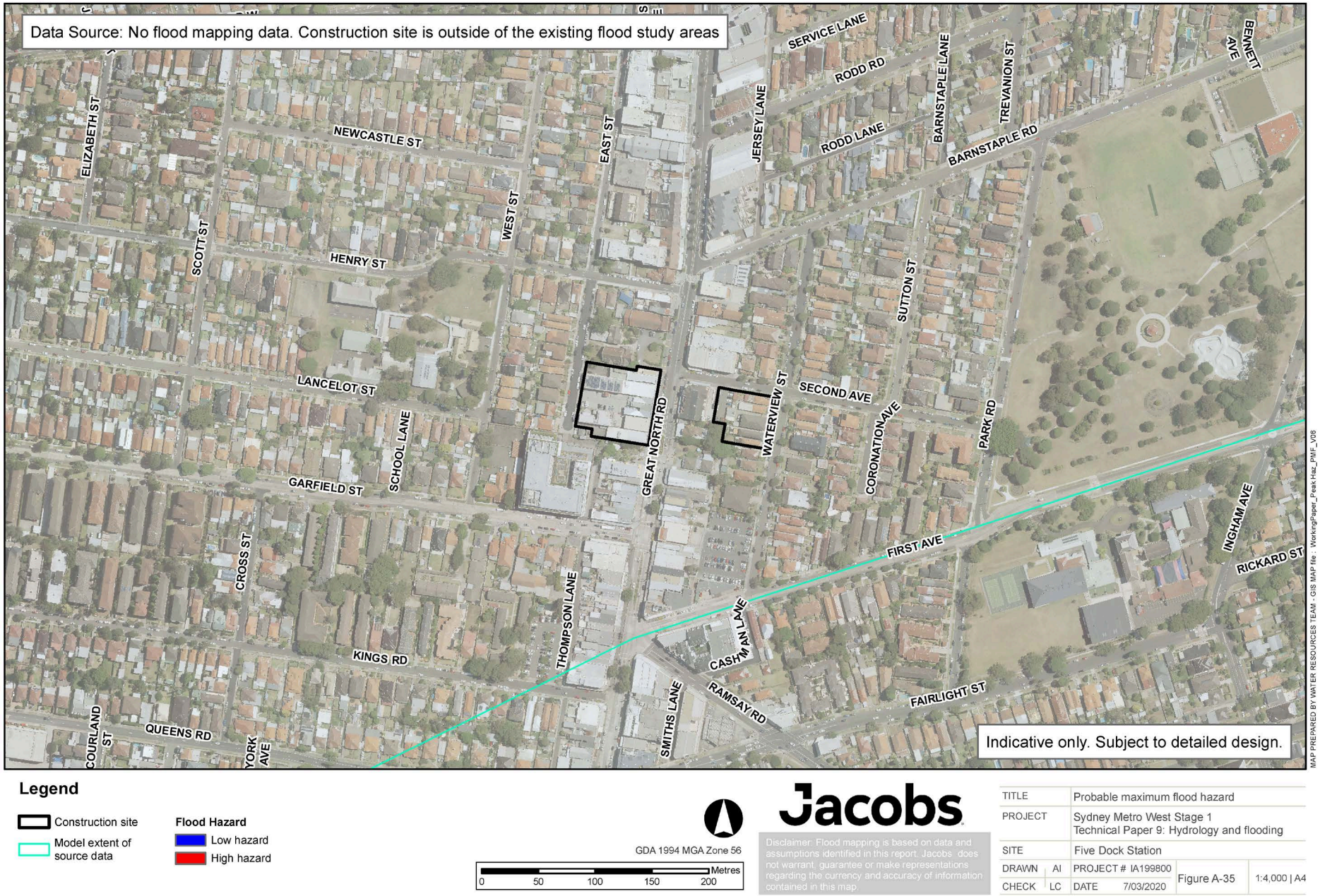


Figure A-35: Five Dock Station - Probable maximum flood hazard

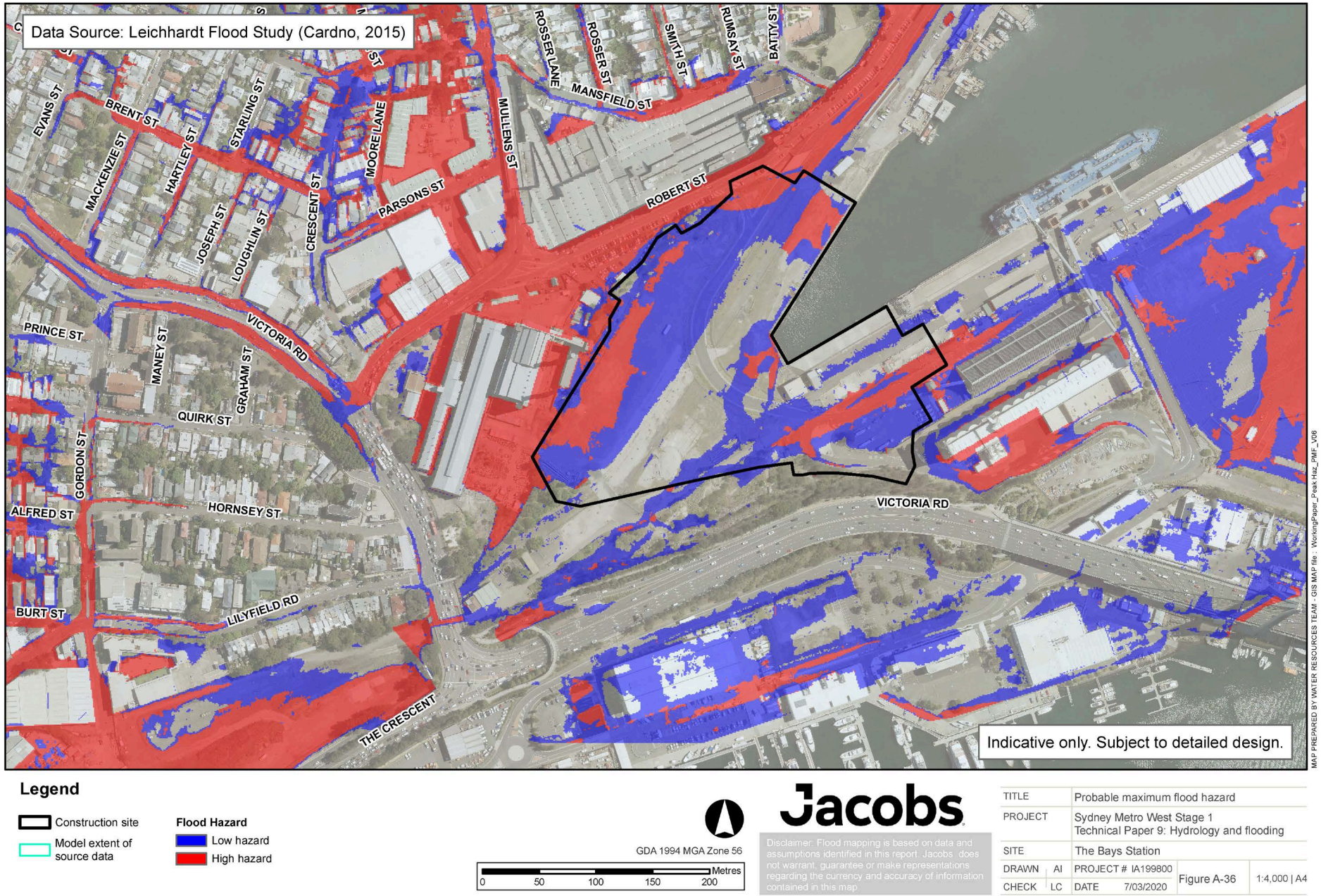


Figure A-36: The Bays Station - Probable maximum flood hazard

Appendix B Summary of flood modelling and impact assessment for Clyde stabling and maintenance facility, Rosehill dive structure and tunnel portal and Rosehill services facility

B.1 Introduction

Quantitative hydraulic modelling has been undertaken for permanent structures that would be constructed at the Clyde stabling and maintenance facility construction site as part of Stage 1. The need for a detailed hydraulic modelling was identified for the Clyde site given the following factors:

- The location of the site on the floodplains of significant watercourses including the Parramatta River, Duck River/Duck Creek and A'Becketts Creek
- The nature of proposed works, with the potential for significant impacts to flood behaviour
- The spatial extent of modelling in the previous flood studies was not sufficient to accurately assess flooding at the site and in the broader floodplain
- Flood levels needed to be estimated to a suitable degree of accuracy in order to set finished levels on the site
- Flood modelling was required to assist in the design of proposed works to ensure no adverse impacts on existing flood behaviour.

The detailed modelling assessed flooding for the final state of the Clyde stabling and maintenance facility Rosehill dive structure and tunnel portal, and the Rosehill services facility. For the purposes of this appendix, this is collectively referred as the "site".

A summary of key aspects of the flood modelling assessment are documented in this appendix.

B.2 Description of existing case modelling

A TUFLOW combined one-dimensional (1D) and two-dimensional (2D) hydraulic model was developed to define existing flooding conditions at and in the area surrounding the site. TUFLOW is an industry-standard flood modelling platform which is widely-used around Australia, and was selected for this assessment as it has:

- Capability in representing complex flow patterns in watercourses and on the floodplain, including flows through street networks and around buildings
- Capability in accurately modelling flow behaviour in 1D channels and interflows with adjacent 2D floodplain areas
- Capability in representing a range of types and configurations of bridges, viaducts, culverts and other hydraulic structures
- Flexibility with representation of proposed case structures
- Consistency and compatibility with the majority of recent flooding studies undertaken in the Parramatta River catchment, mostly conducted in TUFLOW.

B.2.1. Reference existing flood models

The TUFLOW model in this study was developed based on data from the following previous flood study models:

- *Parramatta Light Rail (Stage 1) Flooding Technical Paper* (Arup, 2017)
- *Duck River and Duck Creek Flood Study Review* (WMAwater, 2012)
- *Drainage Master Plan – A'Becketts Creek* (GHD, 2009)
- *Lower Parramatta River Flood Study* (SKM, 2005).

Each of these individual models were not sufficient in extent for this assessment. The terrain and hydraulic structures data from each model were extracted to develop the current TUFLOW model for this assessment.

B.2.2. Model extent

The extents and configuration of the TUFLOW model are shown on Figure B-1 and include:

- The Parramatta River and adjoining floodplain, from upstream of James Ruse Drive to 800 metres downstream of Silverwater Road bridge. The Parramatta River channel was represented further downstream as a one-dimensional channel to Whitton Bridge (Ryde Road)
- Duck River and adjoining floodplain upstream of the Parramatta River confluence to 600 metres upstream of the T1 Western Line
- Duck Creek and adjoining floodplain upstream of Duck River confluence to 400 metres upstream of the T1 Western Line
- A'Becketts Creek and adjoining floodplain upstream of Duck Creek confluence to Harris Street, Harris Park.

B.2.3. Topographic data

The TUFLOW model represents the floodplain areas with a two-dimensional, two metre grid for flood events up to the 1% AEP flood, and a four metre grid for the probable maximum flood. Model terrain was represented based on ground elevations surveyed using LiDAR techniques by NSW Land and Property Information in 2013.

Watercourses are modelled as one-dimensional channels. Channel geometry was extracted from the reference flood study models, which is based on bathymetric survey data undertaken by the former NSW Maritime in the early to mid 2000's of the Parramatta River and tidal sections of Duck Creek and Duck River. Other channel geometry data for non-tidal watercourses was also extracted, and is assumed to be based on survey and design data for constructed channel sections.

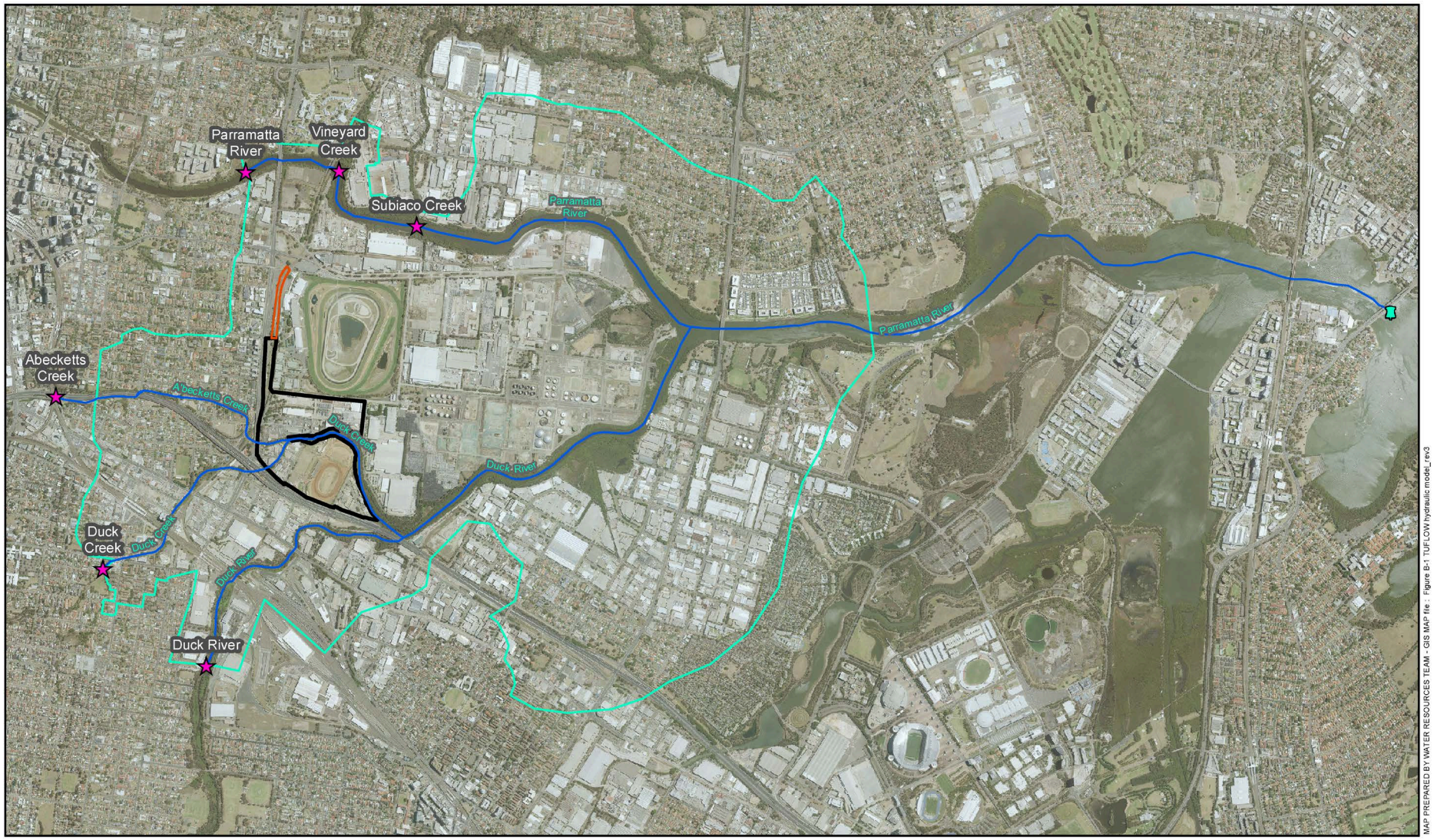


Figure B-1 TUFLOW hydraulic model

B.2.4. Hydrologic inputs

Inflows into Parramatta River, Duck Creek, Duck River and A'Becketts Creek were obtained from the reference flood study models. Catchment hydrology was based on the design rainfalls and procedures in Australian Rainfall and Runoff 1987. Design rainfall depths adopted in the flood study models are generally higher than the recently released Australian Rainfall and Runoff 2019 design rainfall depths for this part of the Sydney region.

Inflows into the Parramatta River from the Upper Parramatta River Catchment are based on "Draft 8" scenario hydrology, which are the design flows adopted by City of Parramatta. "Draft 8" of the Upper Parramatta catchment hydrologic modelling results were released to councils circa 2004 from the Upper Parramatta River Catchment Trust. Draft 8 is understood to have included representation of the implemented flood mitigation works (flood detention basins, etc.) at that time.

Additional hydrologic modelling was undertaken to define minor local catchment and overland flooding in the vicinity of the site for this study using the XP-RAFTS hydrologic mode based on procedures in Australian Rainfall and Runoff 1987.

Model inflows were input into the TUFLOW model at the upstream boundaries of each watercourse, with further inflows input at appropriate locations along the watercourses.

B.2.5. Downstream boundary conditions

Tidal boundary

Design ocean water levels were adopted as time-varying downstream boundary conditions based on *Floodplain Risk Management Guide – Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (OEH, 2015).

Tidal water levels at Whitton Bridge (Ryde Road) are similar to those at Fort Denison in Port Jackson (SKM, 2005), which is classed as having a "Type A" waterway entrance, with peak design ocean levels due to an elevated tide and storm surge event of 1.4 metres AHD in the 5% AEP ocean event and 1.45 metres AHD in the 1% AEP ocean event.

Duck River downstream water levels

Flooding at the site is due to flooding in Duck River and Duck Creek, which is in turn influenced by Parramatta River flooding. Duck River is dynamically linked to the Parramatta River in the TUFLOW model, hence the flood levels in Duck River respond to the time-varying water levels in the Parramatta River as it rises and falls due to the downstream tidal boundary and the flood waves flowing down the Parramatta River as well as from Duck River.

B.2.6. Hydraulic structures

Existing bridges and major culvert crossings were modelled as one-dimensional structures based on information in the reference flood study models.

B.2.7. Hydraulic roughness

The Manning's n hydraulic roughness parameter values adopted in this flood modelling are summarised on Table B-1 and are based on typical values for urban areas and consistent with the current ARR 2019 guidelines. The land use and Manning's n value coverage is mapped on Figure B-2.

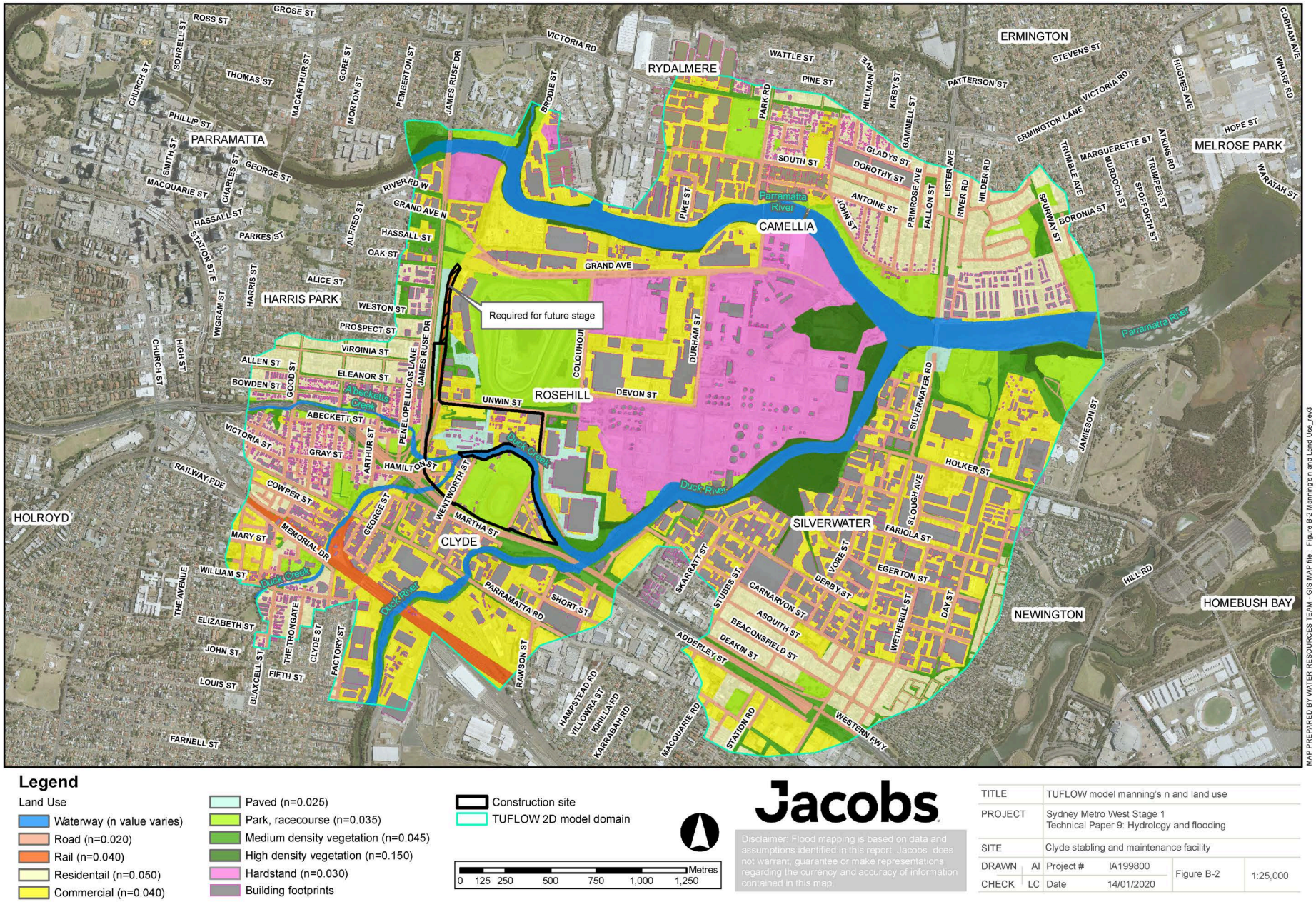


Figure B-2 TUFLOW model Manning's n and land use

Table B-1: Adopted Manning's n values

Land Use Type	Manning's n value
Road	0.02
Rail	0.04
Residential (excluding building)	0.05
Commercial/Industrial lots	0.04
Hardstand, large industrial precinct	0.03
Park, racecourse	0.03
Medium density vegetation	0.045
High density vegetation	0.15
Waterway – Natural	0.03 – 0.06 typical 0.1 on heavily vegetated channel sections of Duck Creek and A'Becketts Creek
Waterway – Concrete lined	0.02

B.2.8. Building footprints

Building footprints were modelled as blocked obstructions in the TUFLOW model. These features redirect flood flows around the buildings as floodwaters interact with the footprints.

B.2.9. Flood events simulated

The 5% and 1% AEP and probable maximum flood events were simulated. The critical storm event durations, producing the peak flood levels in the different waterways, were analysed and include:

- 5% and 1% AEP: two hour duration (Duck River and Duck Creek critical event) and nine hour duration (Parramatta River critical event)
- Probable maximum flood: two hour duration (Duck River and Duck Creek critical event) and four hour duration (Parramatta River critical event).

The site is near the confluence of two major water confluences, namely the Parramatta River and Duck River catchments. The coinciding flood scenarios in each waterway simulated for each flood AEP are summarised in Table B-2. Each event duration was run separately and a maximum flood envelope derived from the modelling results of the two simulations for each AEP. The large extent of each of these catchments means that during extreme flood events (i.e. the probable maximum flood) it is unlikely that a similar magnitude flood would occur at the same time in each waterway. Hence, the probable maximum flood in one waterway was coincided with the 1% AEP event in the other waterway, and vice versa.

Table B-2: Adopted design flood scenarios

Design Flood Envelope AEP	Dominant Flood	Flood Event AEP		
		Parramatta River	Duck River/ Duck Creek	Ocean*
5%	Parramatta River	5% AEP 9 hour	5% AEP 9 hour	HHWS(SS) 1.03m AHD
	Duck River/ Duck Creek	5% AEP 2 hour	5% AEP 2 hour	HHWS(SS) 1.03m AHD
1%	Parramatta River	1% AEP 9 hour	1% AEP 9 hour	5% AEP 1.40m AHD
	Duck River/ Duck Creek	1% AEP 2 hour	1% AEP 2 hour	5% AEP 1.40m AHD
Probable maximum flood	Parramatta River	PMF 4 hour	1% AEP 4.5 hour	1% AEP 1.45m AHD
	Duck River/ Duck Creek	PMF 2 hour	1% AEP 2 hour	1% AEP 1.45m AHD

Abbreviations: "TWL" = Tailwater Level. "HHWS(SS)" = High High Water Spring (Solstice Spring) tide.

* Note: Ocean water levels based on OEH (2015) for locations south of Crowdy Head, NSW.

B.2.10. Climate change assessment

The relevant aspect of climate change impacts on Stage 1 are the potential increase in the flood protection level at the Clyde construction site, which is dictated by the probable maximum flood. Hence, a climate change scenario relating to the year 2100 was assessed to determine the increases in the probable maximum flood level at the site.

Future climate change can affect flood behaviour as a result of increases in storm rainfall intensity and from sea level rise, or a combination of both. Note that while most storms, including that causing the 1% AEP flood event, would expect increases in the storm rainfall intensity, rainfall intensity in the probable maximum flood is not expected to increase. Hence, in estimating the change in probable maximum flood levels the probable maximum flood with no increase in rainfall or flows was modelled combined with a 0.9 metre sea level rise. The 0.9 metre sea level rise was recommended in previous guidance from NSW Government for assessing climate change impacts in the year 2100 which is based on RCP8.5. Representative Concentration Pathways (RCP) 8.5 refers to the upper range projection of greenhouse gas concentrations in the atmosphere as adopted by the Intergovernmental Panel on Climate Change (IPCC) in 2014 for the assessment of climate change impacts.

B.3 Validation of modelling

The design flood levels defined in this assessment for existing conditions were compared to those from the previous studies to validate the current estimates. The previous studies for comparison included those referenced in Section B.2.1 for the building of the current flood model, in addition to other significant flood studies undertaken in the vicinity of the study area. The studies included:

- *Parramatta Light Rail (Stage 1) Flooding Technical Paper* (Arup, 2017)
- *Duck River and Duck Creek Flood Study Review* (WMAwater, 2012)
- *Drainage Master Plan – A'Becketts Creek* (GHD, 2009)
- *Lower Parramatta River Flood Study* (SKM, 2005)
- *Camellia Precinct – Drainage and Flooding Study* (Cardno 2015a).

Flooding conditions at, and potential impacts from, the site are largely concerned with flooding in the Duck River, Duck Creek and A'Becketts Creek system. Comparison of modelled flood levels at key locations are provided in Table B-3. The key locations are shown on Figure B-2.

The design flood levels in the 5% and 1% AEP events at each comparison location are similar and consistent across all of the flood studies reviewed. The design flood levels are within +/- 0.2 metres between each study. These minor variations are likely to be due to slight differences in the modelling approaches or configurations.

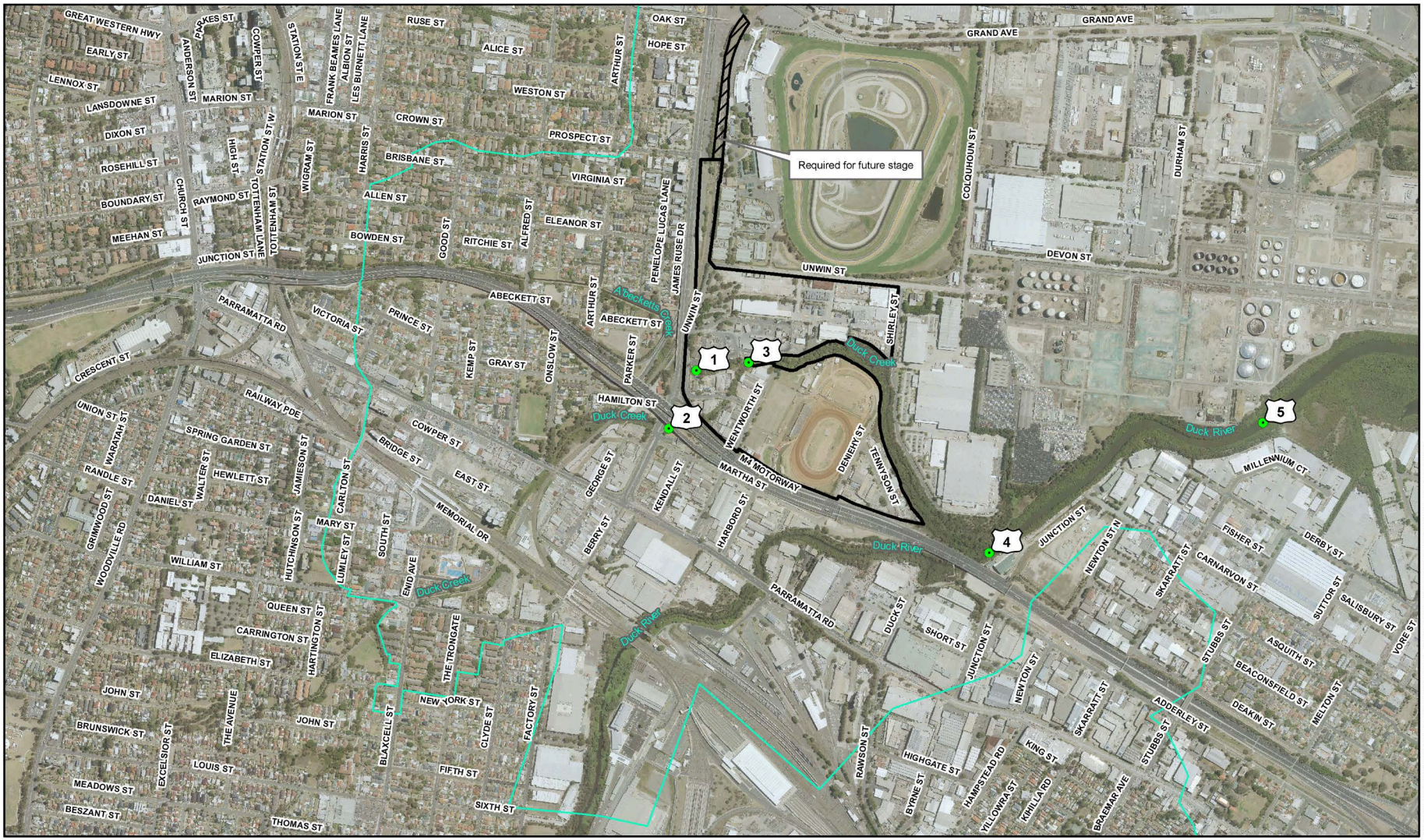
The variations in design flood levels for the probable maximum flood event are markedly greater across the studies. Key observations and issues are summarised below:

- Comparing the flood modelling conducted for Stage 1 to Parramatta Light Rail (Stage 1) flood modelling (Arup, 2017), it was observed that the design flood levels in the current and the previous Arup study are similar (+/- 0.1 metres) for the 5% and 1% AEP events. Flows and water levels in the downstream Parramatta River are similar in the models. The flood levels are about one metre higher in the Arup modelling due to the assumption that the probable maximum flood in the Duck River system would coincide with the probable maximum flood in the Parramatta River catchment. This is considered overly conservative given the relative size of the Upper Parramatta River catchment compared to the Duck River catchment. A probable maximum flood in the Parramatta River coinciding with a 1% AEP flood in Duck River, and vice versa, a 1% AEP flood in the Parramatta River with a probable maximum flood in the Duck River catchment, are more appropriate coincident combinations of the floods and was adopted in this flooding assessment.
- Comparing the flood modelling conducted for Stage 1 to the *Camellia Precinct – Drainage and Flooding Study* (Cardno 2015a), the Cardno modelling is significantly lower by approximately two metres compared to the current study's design probable maximum flood levels, in addition to the other studies. Review of the Cardno probable maximum flood levels indicates similar flood levels to the 1% AEP event in Duck Creek. Given the high magnitude of flows in the probable maximum flood in comparison to the 1% AEP in Duck Creek this suggests a possible issue with the inflow boundary in the Cardno study. The Clyde flood modelling flows in Duck Creek and Duck River were reviewed against the WMAwater (2012) and GHD (2009) flows and were found to be consistent.
- Comparing the flood modelling conducted for Stage 1 to the *Duck River and Duck Creek Flood Study Review* (WMAwater, 2012), it was observed that the WMAwater design probable maximum flood levels at the site are about 0.5 to one metre higher than the current study. This is attributed to the WMAwater model's downstream boundary condition. The WMAwater model represents Duck River and Duck Creek only, and adopted the peak probable maximum flood level (four hour storm duration) in the Parramatta River as a constant tailwater level for the Duck River probable maximum flood simulation (two hour storm duration). This is considered highly conservative as due to the differing sizes of the Parramatta River and Duck River catchments and the different critical storm durations the Duck River flood is unlikely to peak at the same time as Parramatta River. Additionally, in contrast the 1% AEP Parramatta River flood was assumed to

coincide with the Duck River probable maximum flood in the current study. Hence it is considered that the high Parramatta River tailwater level in the WMAwater model causes the high probable maximum flood level estimates in Duck Creek at the site, and the current study provides a less conservative but appropriate probable maximum flood level estimate at the site.

- Comparing the Clyde flood modelling to the *Lower Parramatta River Flood Study* (SKM, 2005), it was observed that the SKM flood model estimated probable maximum flood levels around one metre higher at the Duck River and Duck Creek confluence. The SKM flood model consisted of a one-dimensional MIKE11 model with the waterway channels and floodplain represented as one-dimensional cross sections. Review of the MIKE11 model indicated that the cross section at this location is highly truncated and the flood levels are not allowed to spread onto the more extensive floodplain, hence resulting in the higher flood level estimate.

Based on the model validation review of other flood studies it is considered that the flood modelling conducted for Stage 1 provides appropriate estimates of design flood levels at the site and that the marked differences to some other flood studies can be reasonably justified.



Legend

- Construction site
- Validation locations
- Extent of flood mapping

GDA 1994 MGA Zone 56

0 125 250 500 Metres

Jacobs

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

TITLE	Model validation locations				
PROJECT	Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding				
SITE	Clyde stabling and maintenance facility				
DRAWN	AI	Project #	IA199800	Figure B-3	1:15,000
CHECK	LC	Date	14/01/2020		

Figure B-3 Model validation locations

Table B-3 Validation of modelled flood levels against previous studies

ID	Location	Current flooding assessment	Parramatta Light Rail (Stage 1) (ARUP, 2017)	Camellia Precinct – Drainage and Flooding Study (Cardno 2015a)	Drainage Master Plan – A'Becketts Creek (GHD, 2009)	Duck River and Duck Creek Flood Study Review, WMAwater, 2012)	Lower Parramatta River Floodplain Risk Management Study (SKM, 2005)
5% AEP Flood Levels (metres AHD)							
1	Downstream of Unwin Street, A'Becketts Creek	**4.7**	-	-	4.9	-	-
2	Downstream of James Ruse Drive, Duck Creek	**5.0**	-	-	-	4.6	
3	Confluence of Duck Creek and A'Becketts Creek	**4.6**	-	-	-	4.4	
4	Confluence of Duck River and Duck Creek	**3.6**	-	-	-	3.7	3.5
5	Duck River at Fariola Street, Silverwater	**3.1**	2.9	-	-	~3.1	2.9
6	Confluence of Duck River and Parramatta River	**2.6**	2.7	-	-	~2.7	2.7
1% AEP Flood Levels (metres AHD)							
1	Downstream of Unwin Street, A'Becketts Creek	**5.1**	-	-	5.3	-	-
2	Downstream of James Ruse Drive, Duck Creek	**5.3**	-	4.7	-	5.0	-
3	Confluence of Duck Creek and A'Becketts Creek	**5.0**	-	4.7	-	4.9	
4	Confluence of Duck River and Duck Creek	**4.0**	-	3.9	-	4.2	4.1
5	Duck River at Fariola Street, Silverwater	**3.5**	3.4	-	-	~3.5	3.3
6	Confluence of Duck River and Parramatta River	**3.1**	3.2	3.1	-	~3.2	3.2

ID	Location	Current flooding assessment	Parrmatta Light Rail (ARUP, 2017)	Camellia Precinct – Drainage and Flooding Study (Cardno 2015a)	Drainage Master Plan – A'Becketts Creek (GHD, 2009)	Duck River and Duck Creek Flood Study Review, WMAwater, 2012)	Lower Parramatta River Floodplain Risk Management Study (SKM, 2005)
Probable Maximum Flood Levels (metres AHD)							
1	Downstream of Unwin Street, A'Becketts Creek	**6.5**	-	-	-	-	-
2	Downstream of James Ruse Drive, Duck Creek	**6.7**	-	4.7	-	7.1	-
3	Confluence of Duck Creek and A'Becketts Creek	**6.4**	-	4.7	-	6.9	-
4	Confluence of Duck River and Duck Creek	**5.8**	-	4.6	-	6.8	6.7
5	Duck River at Fariola Street, Silverwater	**4.9**	5.8	-	-	~5.7	5.7
6	Confluence of Duck River and Parramatta River	**4.8**	5.6	4.5	-	~5.6	5.6

Note: Blank cell denotes flood level not assessed or not available at this location.

B.4 Modelling of Stage 1

Hydraulic modelling was undertaken for Stage 1, which involves a number of permanent works at the site, including:

- Filled formation at Clyde stabling and maintenance facility site, constructed to a finished level of 8.3 metres AHD (top of rail)
- A dive structure and tunnel portal to the north of the stabling and maintenance facility located between Rosehill Gardens racecourse and James Ruse Drive. The top of rail level at dive crest would be at 8.3 metres AHD, set based on a flood protection level of the probable maximum flood level at the dive crest and allowing for thickness of track slab and track height. Flood-proofing retaining walls would surround the dive structure and tunnel portal
- Land formations to cater for the future metro rail tracks into and out of the maintenance and stabling facility would cross Duck Creek and A'Becketts Creek at their confluence. The tracks would continue north from the crossing to the dive structure and tunnel portal, then descend underground to join the Sydney Metro West tunnels between Parramatta metro station and Sydney Olympic Park metro station
- New culvert crossing structure for the future tracks. The structure consists of twin six metre height by nine metre wide arch culverts on each creek channel. There would be realignment of both creek channels at their confluence to realign their flow paths, including sections of open channel to the south of the proposed creek crossings. A new open channel to the north of A'Becketts Creek would also be constructed to convey floodplain flows originating from areas to the west of James Ruse Drive. This would be designed for events up to and including the probable maximum flood event. The open channels and culverts discharge to Duck Creek downstream of the Duck Creek and A'Becketts Creek crossing
- Unwin Street would be reconstructed to provide public road access around the Clyde stabling and maintenance facility. The reconstructed road would cross over the rail track connecting the stabling and maintenance facility and the tunnel dive via a bridge structure, with a filled embankment constructed at the northern bridge approach. The southern bridge approach would form part of the stabling and maintenance facility filled embankment
- A services facility would be situated on a separate parcel of land to the north-east of the stabling and maintenance facility within the construction site
- All buildings within the construction site were removed.

Refer to Figure B-4 for design details and layout.

The existing case TUFLOW model was updated to represent the operational phase features. This model was used to determine the potential flood impacts without additional flood impact mitigation works and measures.

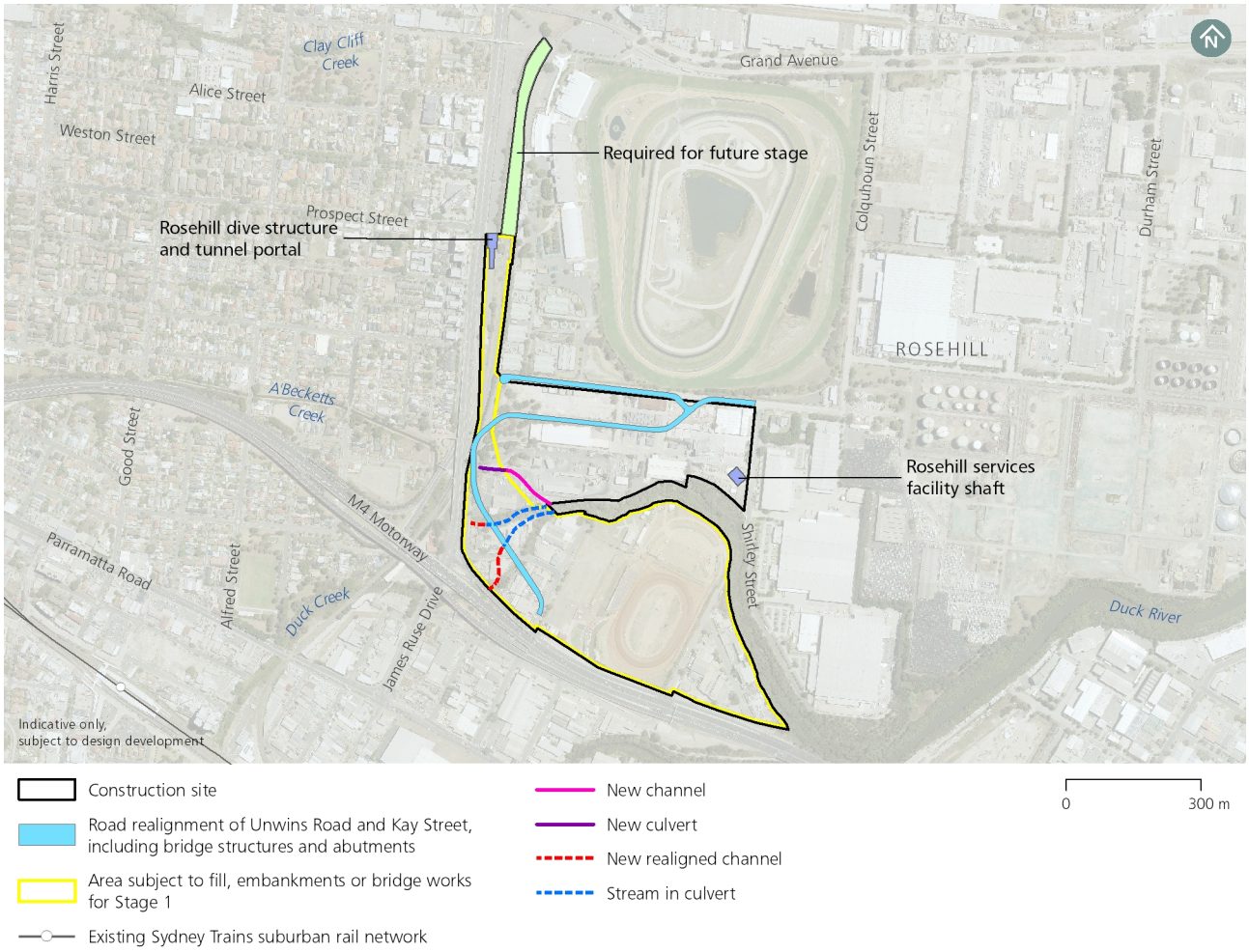


Figure B-4: Clyde stabling and maintenance facility layout (key design features)

B.4.1. Estimation of flooding impacts

The operational case of the Clyde stabling and maintenance facility was simulated in the TUFLOW model for the 5% and 1% AEP events and probable maximum flood. Mapping showing the flood impact (change in flood levels) is shown on Figures B-11 to B-13, and the change in flood hazard is shown on Figures B-14 to B-16. Note that Stage 1 construction phase is similar to operational phase with regards to influence on flooding. Outcomes of the design case modelling are discussed below.

Change in peak flood levels

Peak flood levels on the Duck Creek and A'Becketts Creek floodplains upstream of the Clyde stabling and maintenance facility are reduced in the 5% and 1% AEP events, by up to 0.1 metres, as a result of Stage 1. This is caused by the new crossings and formalising of sections of the creek channels, which would increase the flow capacity of the channels for these flood events.

There are increases in flood levels in the 5% and 1% AEP event of up to 0.08 metres in and adjacent to Duck Creek and Duck River downstream of the culvert crossings. Encroachment of the stabling and maintenance facility filled embankment on the creek bank, at a location 500 metres upstream of the Duck Creek and Duck River confluence, contributes to the increased flood levels due to reduction of floodplain storage and reduction of floodplain flow conveyance. These increased flood levels appear to be below the floor levels of existing buildings affected. This would need to be confirmed with detailed survey. Opportunities to minimise increases would occur during detailed design and would be informed by floor level surveys of existing properties.

These flood level increases extend back up Duck River to upstream of the M4 Motorway, with an increment in the 5% and 1% AEP flood levels of 0.01 to 0.02 metres, but do not affect any new properties in this area.

In the probable maximum flood event, flood levels are increased both upstream and downstream of the Clyde stabling and maintenance facility construction site as a result of reduction in flow conveyance on the floodplain due to the obstruction by the filled embankment of the stabling and maintenance facility and the new road bridge embankment. Loss of floodplain storage due to the embankment is also likely to contribute to the impacts. The change in flood levels include up to 0.07 metres increases in the A'Becketts Creek floodplain, 0.15 metres in the Duck Creek floodplain upstream of the culvert crossing, up to 0.06 metres in Duck Creek downstream of the culvert crossing and 0.1 metres in the Duck River floodplain, upstream of the M4 Motorway. Increases of up to 0.2 metres occur on the south-western section of Rosehill Gardens racecourse grounds.

Maximum increases in flood levels in the probable maximum flood are around 0.5 metres as a result of Stage 1. These effects are localised and occur in currently flooded areas under the James Ruse Drive viaduct, and do not impact on private property.

In relation to the design criteria and performance outcomes discussed in Section 2.2, these flood level increases do not result in a significant impact to the flood hazard or trafficability of roads and emergency access routes (refer to Section 4.2.2.3 and Section 4.5) since the affected roads are already impacted by high flood depths and hazard in the existing case. Hence these are considered tolerable increases in the probable maximum flood.

Change in flood extent

Increases in peak flood levels as a result of Stage 1 are relatively small in increment, resulting in minimal increases in the flood extent for all events up to the probable maximum flood. Maximum increases in the probable maximum flood extent are around 10 metres, and typically less than five metres. There are approximately seven properties which would become newly-affected by flooding in the probable maximum flood. There are no new properties affected in the 5% and 1% AEP flood events.

The changes in flood extent from existing to developed case are shown on Figures B-11 to B-13.

Change in flood hazard

The change in flood hazard has been mapped on Figure B-14 to B-16 to indicate areas where flood hazard increases from low (H1 and H2 hazard rating) or not flooded, to high (H3 rating and higher), and where the flood hazard decreases from high to low or not flooded. The mapping is presented for the 5% and 1% AEP and probable maximum flood events.

There is generally a reduction in flood hazard in the 5% and 1% AEP events, with a predominant shift in areas previously with high hazard to a low hazard rating, or becoming not flooded. This occurs mainly in areas upstream of the Clyde site and is a result of reductions in flood levels of up to 0.1 metres in those areas. There are localised areas where the flood hazard changes from low or not flooded up to high hazard. This is a result of the increase in flood levels in Duck Creek and the adjacent floodplain of up to 0.08 metres, in addition to channel realignment works in Duck Creek upstream of the stabling and maintenance facility culvert crossing changing the extent of inundation. The increase in high hazard extent, where these do occur, is up to 10 metres but are typically less than five metres. There are marginal increases to high hazard areas in properties on Duck River upstream of the M4 Motorway resulting from the 0.02 metres increase in flood depths in that area.

The changes in flood hazard in the probable maximum flood are predominated by an increase to high hazard rating, resulting from the typical increases in flood levels of 0.1 to 0.2 metres. Most of the increases in extent are less than eight metres horizontally.

Roads are generally affected by only marginal increases in the extent of the high flood hazard areas. There are no new roads which become significantly affected by high hazard flooding as a result of Stage 1.

Change in duration of inundation

Substantial increases in the duration of inundation can result in increased flood damage to property due to the longer exposure to floodwaters. Figures B-18 to B-21 show plots of the 1% AEP flood depth with time, over the course of the flood event at four selected locations on A'Becketts Creek, Duck Creek and Duck River, which are shown on Figure B-17. Plots are shown for both the two hour event and nine hour event.

The plots show that flood depths vary over the course of the flood events in a similar manner in both the existing case and the developed case (i.e. with Stage 1). The duration of inundation is reduced on A'Becketts Creek and Duck Creek due to the higher flow conveyance in the creeks from the formalising and culverting of the channels on the Clyde site, conveying floodwaters more efficiently. Flow velocities in the culvert section increase by about 18 percent from 0.8 to 0.94 metres per second. There are slight increases in the duration of inundation on two locations on Duck River of less than 10 minutes, although these are not substantial increases. Hence, it is not expected that there would be significant increases in the duration of flooding or a resulting increase in flood damages as a result of Stage 1.

Impacts to property

The increases in flood levels and depths in the 5% and 1% AEP events are generally minor, with some industrial properties adjacent to Duck River in Auburn expected to experience minor increases of 0.01 to 0.02 metres. The largest increase in flood levels (of around 0.08 metres) occurs near the Duck Creek and Duck River confluence and affects several commercial and industrial properties. These increased flood levels appear to be below the floor levels of existing buildings affected. Design refinement should be considered at detailed design stage to mitigate these flood level increases and potential impacts to properties.

Flood level increases on properties in the probable maximum flood event are generally 0.04 to 0.08 metres, with a maximum increase on properties of up to 0.2 metres on the Rosehill Gardens racecourse grounds. Given the rarity of such an event and the high depths and wide extent of flooding in this event under existing conditions, it is expected that there would be significant flooding damage already irrespective of Stage 1 in the baseline case

and the resulting increase in flood levels in the developed case due to Stage 1 would not cause a material increase in flooding impacts to property.

No new properties were identified as becoming flood-affected in up to the 1% AEP event as a result of Stage 1.

Impacts to roads and vehicle access

The increases in flooding depths in up to the 1% AEP event are minor, with some areas of reduced flood depths. The trafficability of roads including for emergency access would not be impacted as a result in these events.

In the probable maximum flood event the maximum 0.1 metre increase in flood depths on roads is not expected to result in a material impact to the trafficability of roads, since the roads in the vicinity of the site would already be submerged with significant depths of flooding of over two metres in the baseline case (without Stage 1). The minor increase in probable maximum flood extent due to Stage 1 would also not result in the affectation of additional roads and emergency access routes.

B.4.2. Climate change assessment

A climate change assessment has been undertaken for flooding at the site to determine the impacts of flooding resulting from Stage 1 and the impacts of changed flooding conditions on the permanent structures that would be constructed as part of Stage 1. Relevant to the Stage 1 flooding assessment is the impact of climate change on flood immunity of permanent features included in Stage 1.

Flood immunity of the Stage 1 structures are dictated by the probable maximum flood levels at the tunnel dive structure. Finished levels across the stabling and maintenance facility area on filled embankment are fixed by the dive crest level. The change in the probable maximum flood levels was assessed by including a sea level rise increment of 0.9 metres to the design flood tailwater conditions, which corresponds to the projected sea levels in the year 2100 relative to year 1990 baseline sea levels. Climate change is expected to also increase storm rainfall and result in flood flow increases, but would only affect storm events up to the 1% AEP event. There would not be an increase in the probable maximum flood event rainfall intensity as a result of climate change.

The probable maximum flood level at the tunnel dive crest in the current climate is 7.08 metres AHD. The modelling indicates that the dive structure and tunnel portal is above the influence of sea level rise in the year 2100 and under the climate change scenario the probable maximum flood level remains at 7.08 metres AHD.

B.5 Conclusions and recommendations

- Stage 1 results in generally minor flooding impacts. Flood levels increase in localised areas of Duck Creek and adjoining areas by up to 0.08 metres in the 5% and 1% AEP events. These increased flood levels appear to be below the floor levels of existing buildings affected. This would need to be confirmed with detailed survey. Areas upstream of the site generally experience a reduction in flood levels by up to 0.1 metres
- Impacts in the probable maximum flood are generally increases in flood levels of 0.1 to 0.2 metres, which are considered minor in the context of the large magnitude and extent of this extreme flood event. There are localised increases in flood levels of around 0.5 metres, which occur in currently flooded areas under the James Ruse Drive viaduct, and does not impact on private property
- Maximum increases in the probable maximum flood extent are around 10 metres, and typically less than five metres
- The increase in high flood hazard extent is generally minor in the 5% and 1% AEP and probable maximum flood events. Roads are generally affected by only marginal increases in the extent of the high flood hazard areas. There are no new roads which become significantly affected by high hazard flooding as a result of Stage 1

- No new properties were identified as becoming flood-affected in up to the 1% AEP event as a result of Stage 1. Up to seven new properties become flood-affected in the probable maximum flood. Opportunities to minimise increases in the 1% AEP event would occur during detailed design and would be informed by floor level surveys of existing properties
- There is not expected to be material impacts to the trafficability of roads and emergency access routes. The increases in flood depths of 0.1 metres on roads in the probable maximum flood would not affect trafficability as these roads are already deeply submerged in the existing case.

B.6 Attachments – Flood Mapping Figures

Figure B-5: Existing case flood depths and levels – 5% AEP event

Figure B-6: Existing case flood depths and levels – 1% AEP event

Figure B-7: Existing case flood depths and levels – Probable maximum flood

Figure B-8: Existing case flood hazard – 5% AEP event

Figure B-9: Existing case flood hazard – 1% AEP event

Figure B-10: Existing case flood hazard – Probable maximum flood

Figure B-11: Stage 1 case change in flood levels – 5% AEP event

Figure B-12: Stage 1 case change in flood levels – 1% AEP event

Figure B-13: Stage 1 change flood levels – Probable maximum flood

Figure B-14: Stage 1 case change in flood hazard – 5% AEP event

Figure B-15: Stage 1 case change in flood hazard – 1% AEP event

Figure B-16: Stage 1 change in flood hazard – Probable maximum flood

Figure B-17: Duration of inundation reporting locations

Figure B-18: Flood level versus time – 1% AEP event, A'becketts Creek upstream of James Ruse Drive

Figure B-19: Flood level versus time – 1% AEP event, Duck Creek upstream of M4 Motorway

Figure B-20: Flood level versus time – 1% AEP event, Duck River upstream of M4 Motorway

Figure B-21: Flood level versus time – 1% AEP event, Duck River near Fariola Street, Silverwater

Figure B-22: Climate change impact assessment – Probable maximum flood event

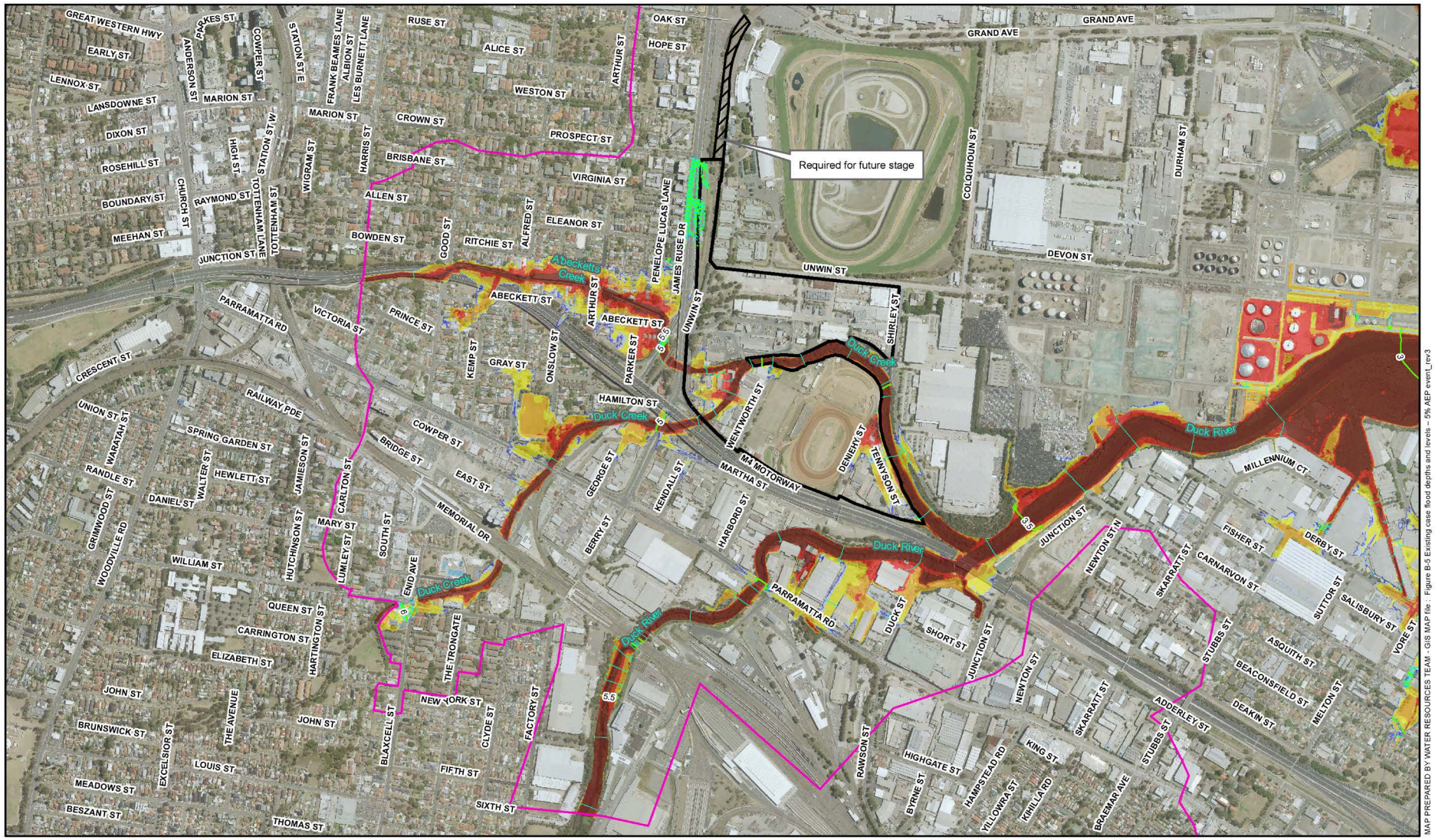
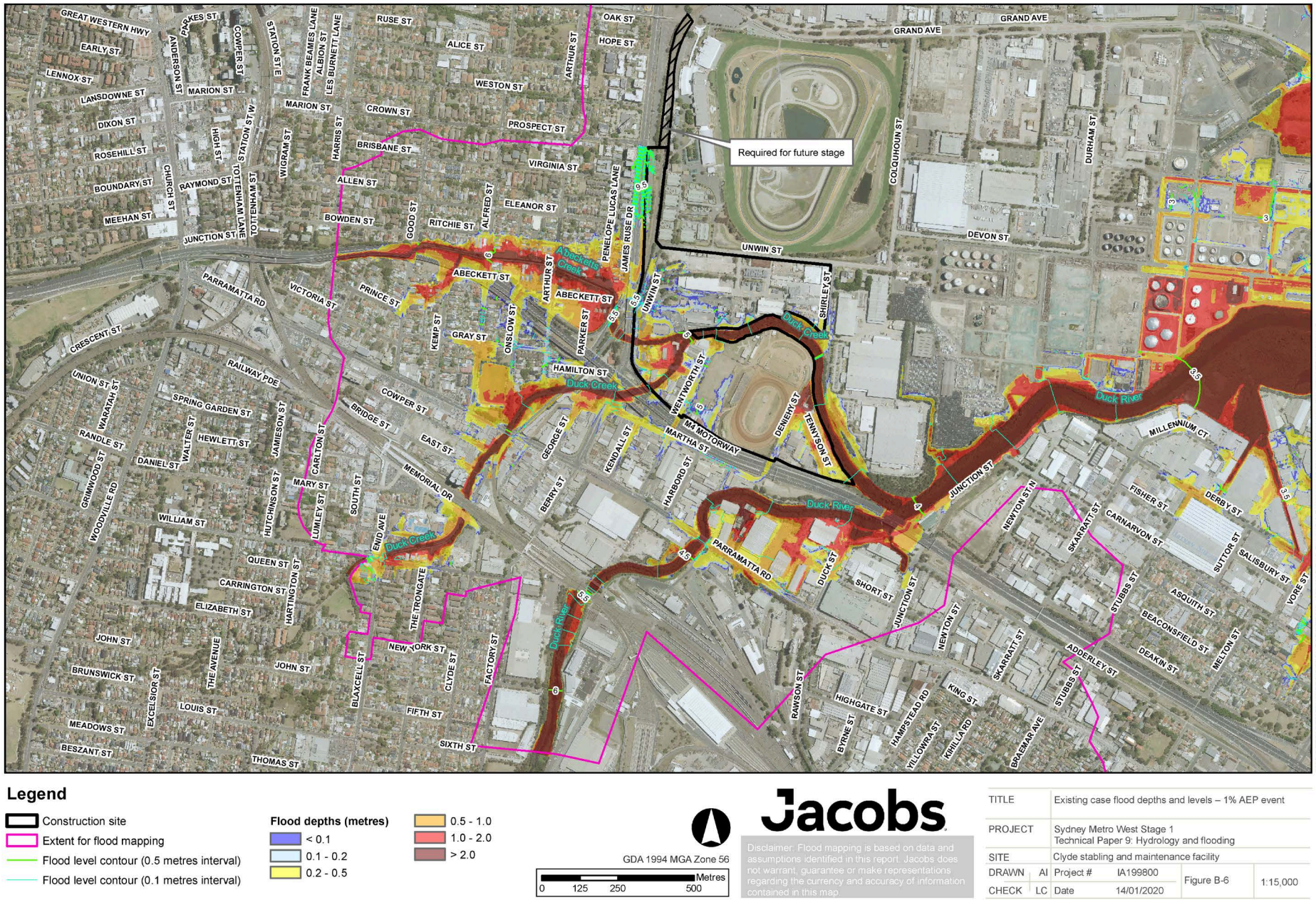


Figure B-5: Existing case flood depths and levels – 5% AEP event



Legend

- Construction site
- Extent for flood mapping
- Flood level contour (0.5 metres interval)
- Flood level contour (0.1 metres interval)

Flood depths (metres)

- < 0.1
- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

GDA 1994 MGA Zone 56

0 125 250 500 Metres

Jacobs

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

TITLE	Existing case flood depths and levels – 1% AEP event				
PROJECT	Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding				
SITE	Clyde stabling and maintenance facility				
DRAWN	AI	Project #	IA199800	Figure B-6	1:15,000
CHECK	LC	Date	14/01/2020		

Figure B-6: Existing case flood depths and levels – 1% AEP event

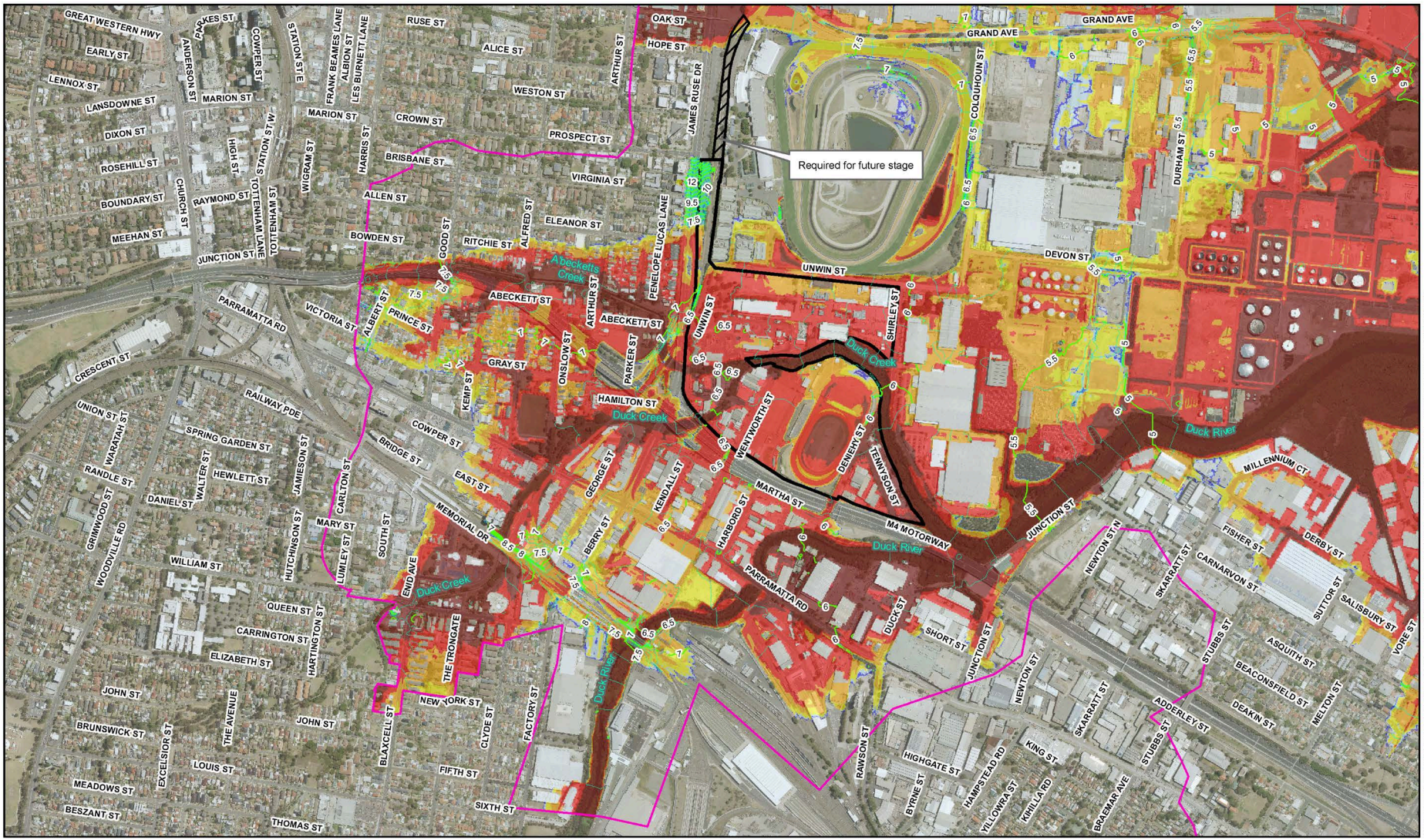
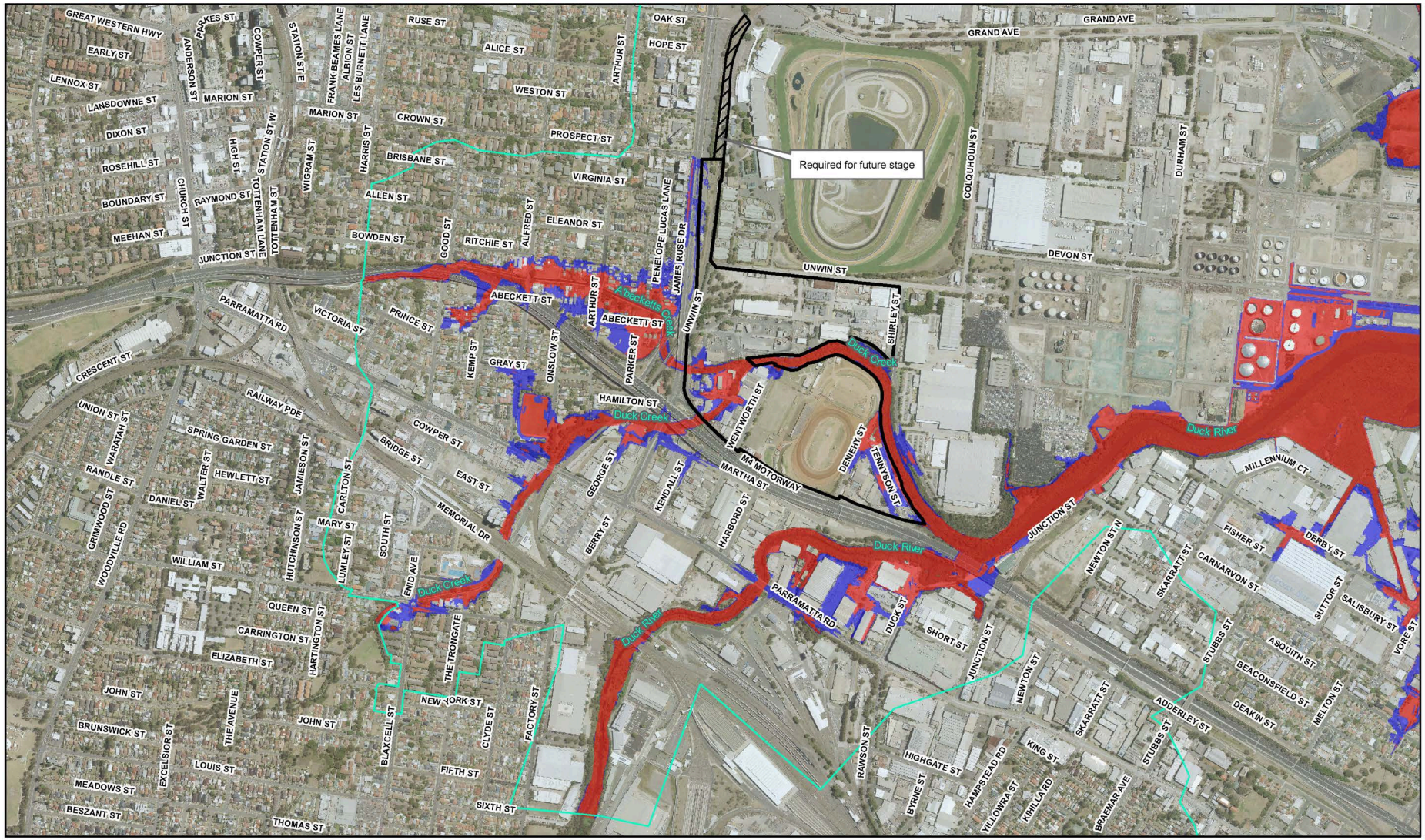


Figure B-7: Existing case flood depths and levels – Probable Maximum Flood event



Legend

- Construction site
- Extent for flood mapping

Flood hazard

- Low hazard
- High hazard

GDA 1994 MGA Zone 56

0 125 250 500 Metres

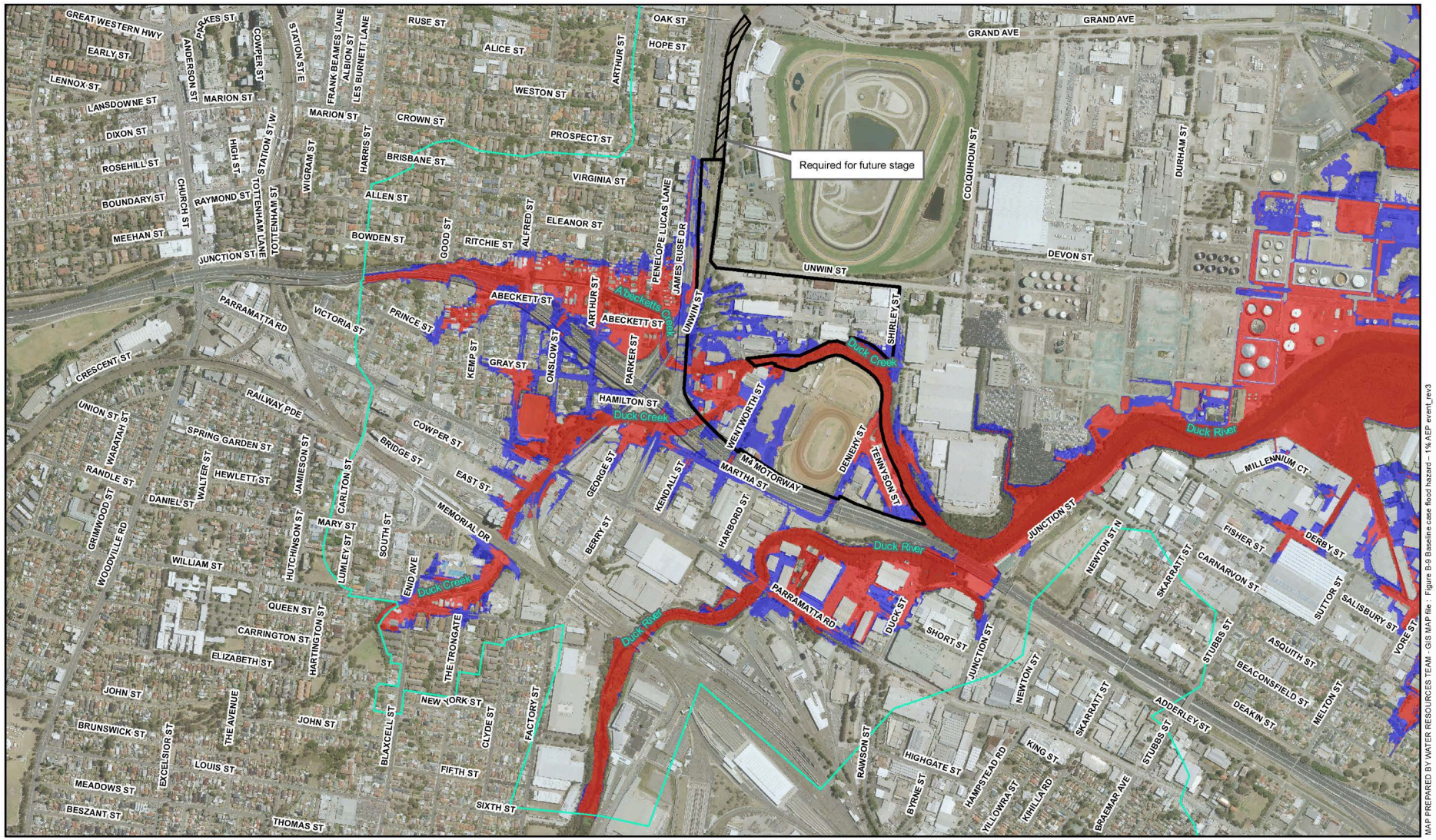
Jacobs

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

TITLE	Existing case flood hazard – 5% AEP event				
PROJECT	Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding				
SITE	Clyde stabling and maintenance facility				
DRAWN	AI	Project #	IA199800	Figure B-8	1:15,000
CHECK	LC	Date	14/01/2020		

MAP PREPARED BY WATER RESOURCES TEAM - GIS MAP file: Figure B-8 Existing case flood hazard – 5% AEP event_rev3

Figure B-8: Existing case flood hazard – 5% AEP event



Jacobs

TITLE	Existing case flood hazard – 1% AEP event				
PROJECT	Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding				
SITE	Clyde stabling and maintenance facility				
DRAWN	AI	Project #	IA199800	Figure B-9	1:15,000
CHECK	LC	Date	14/01/2020		

Figure B-9: Existing case flood hazard – 1% AEP event

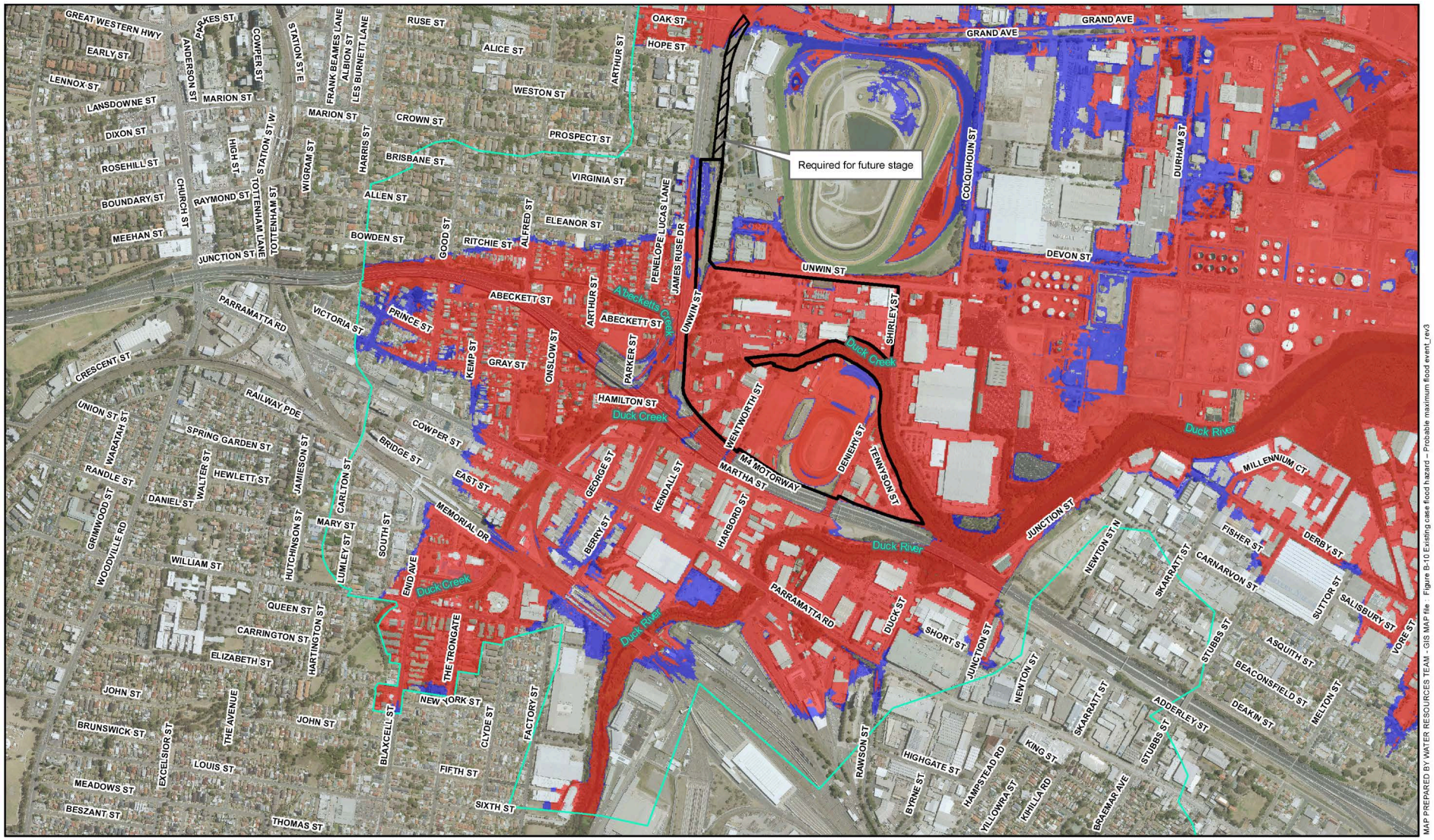


Figure B-10: Existing case flood hazard – Probable Maximum Flood event

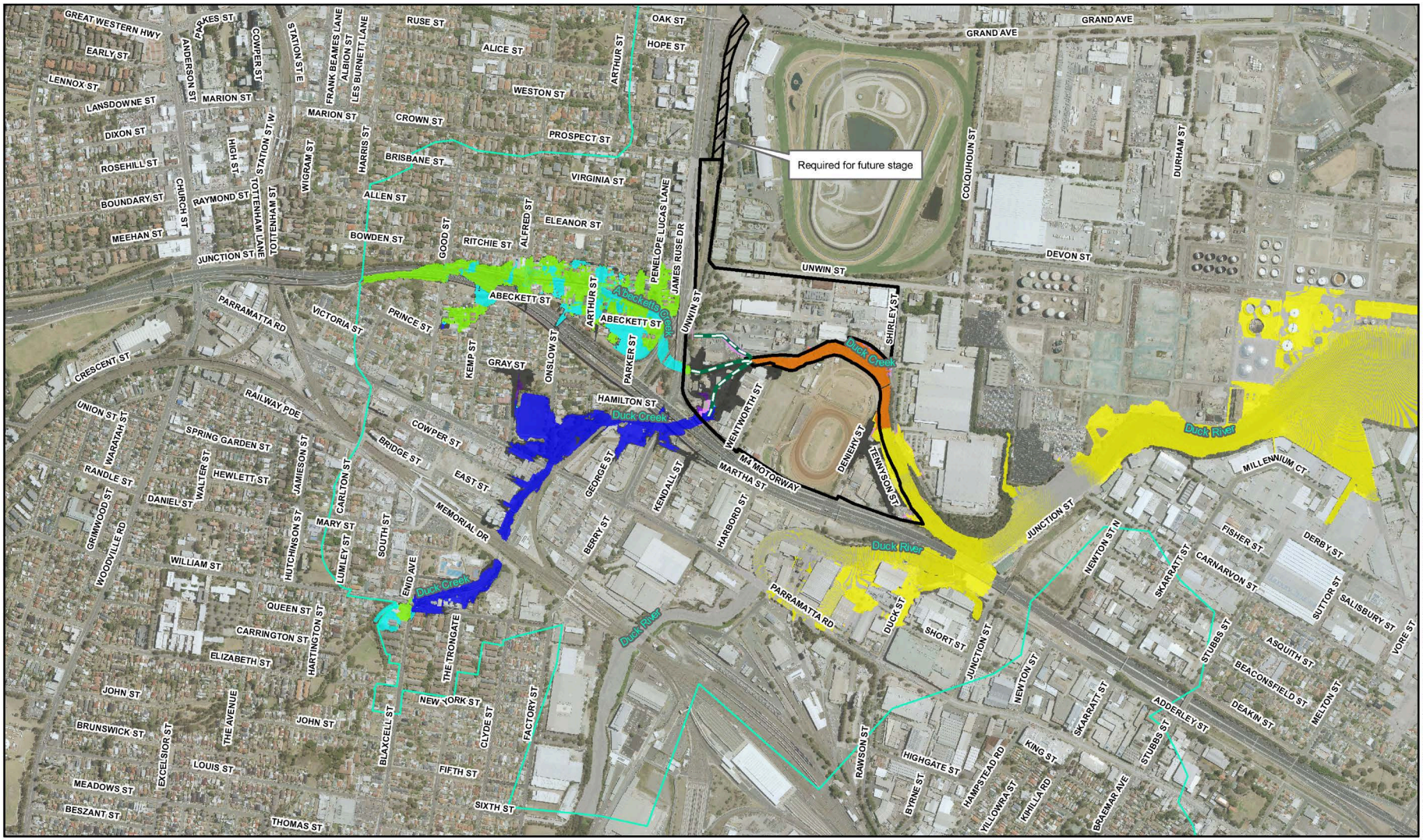


Figure B-11: Developed case change in flood levels – 5% AEP event

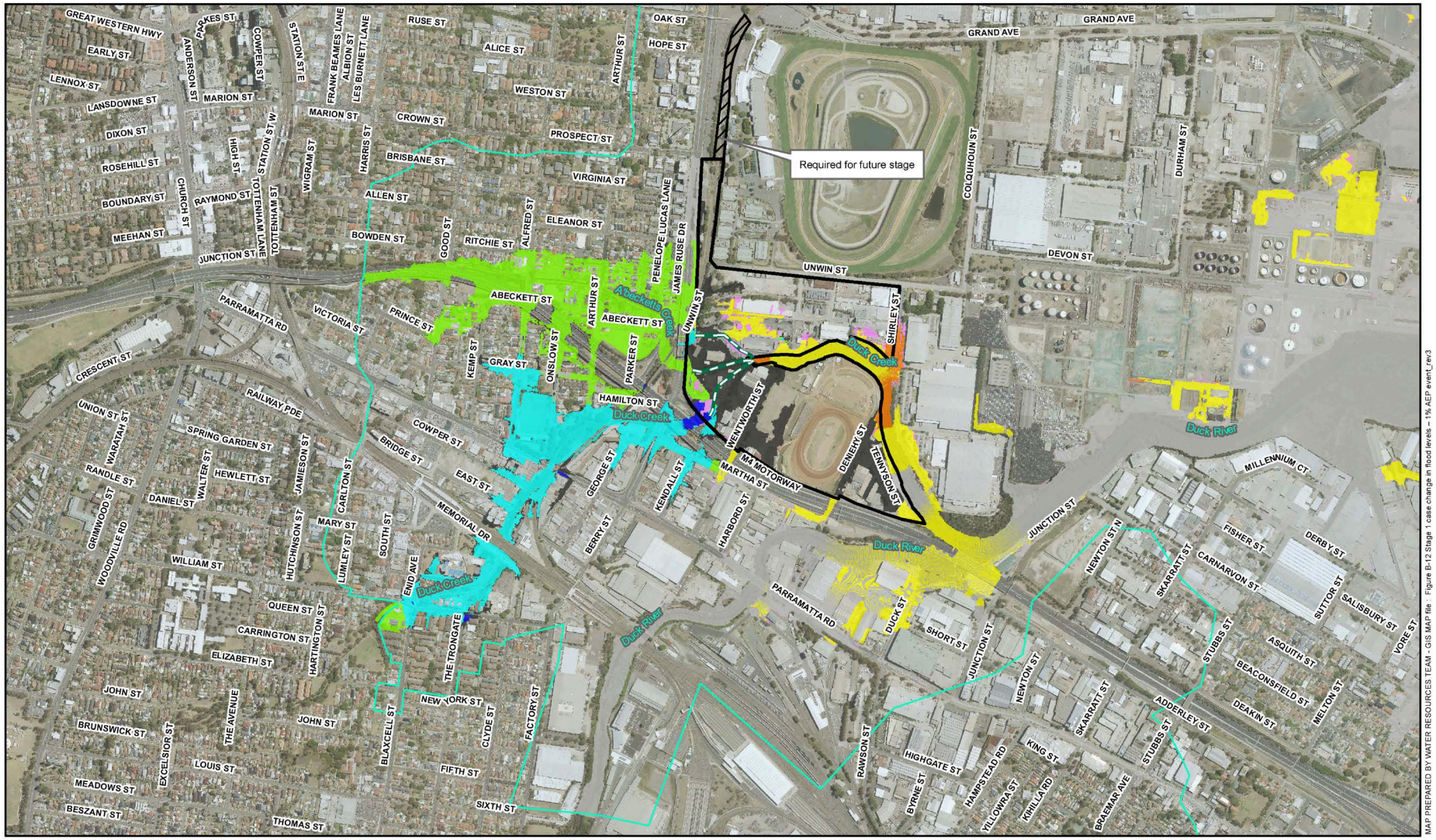
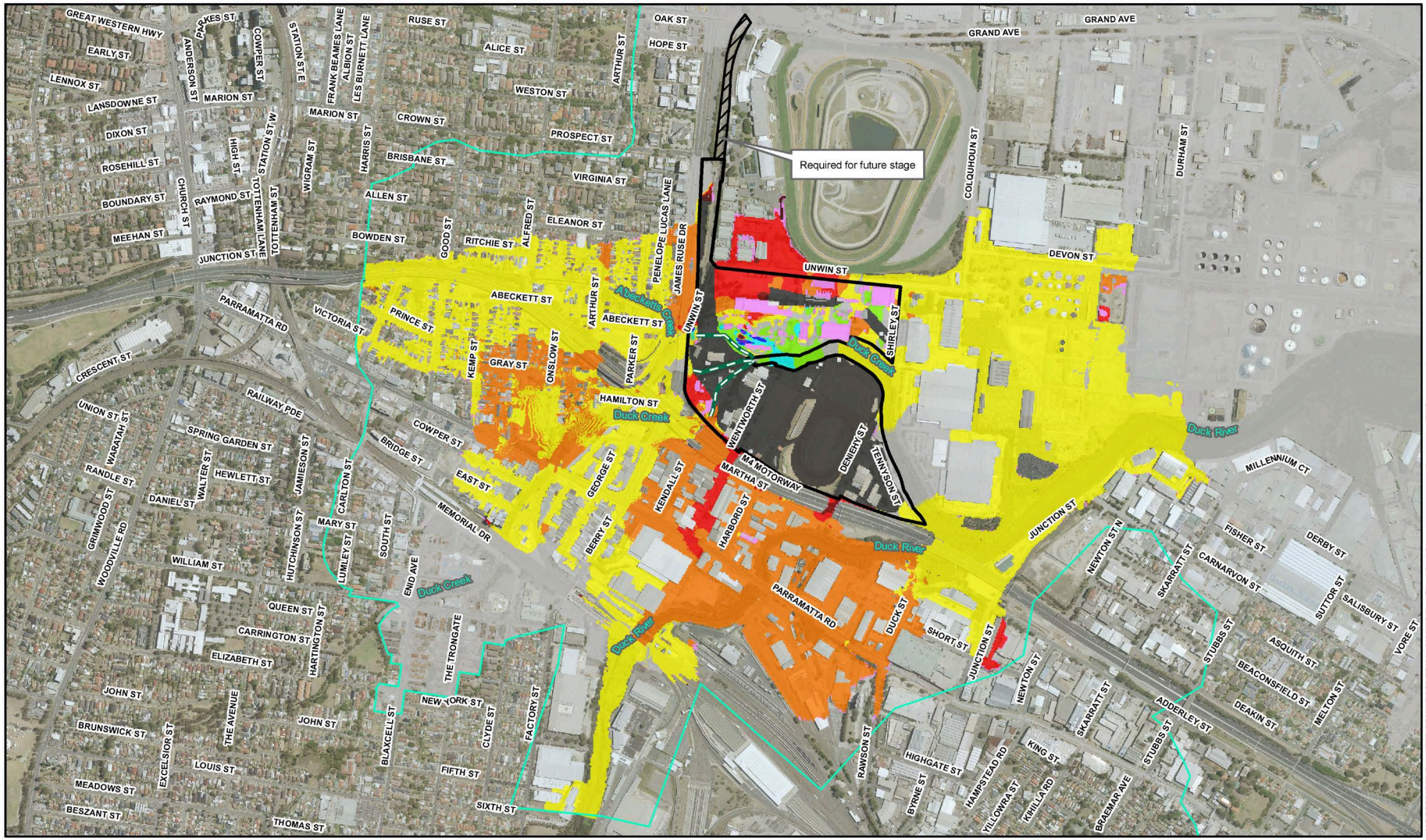


Figure B-12: Developed case change in flood levels – 1% AEP event



Legend

- Construction site
- Extent for flood mapping
- Proposed culverts

Change in flood levels (metres)

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- >0.30
- Was dry now wet
- Was wet now dry

GDA 1994 MGA Zone 56

0 125 250 500 Metres

Jacobs

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

TITLE	Stage 1 case change flood levels – Probable maximum flood				
PROJECT	Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding				
SITE	Clyde stabling and maintenance facility				
DRAWN	AI	Project #	IA199800	Figure B-13	1:15,000
CHECK	LC	Date	15/01/2020		

Figure B-13: Developed case change flood levels – Probable Maximum Flood event

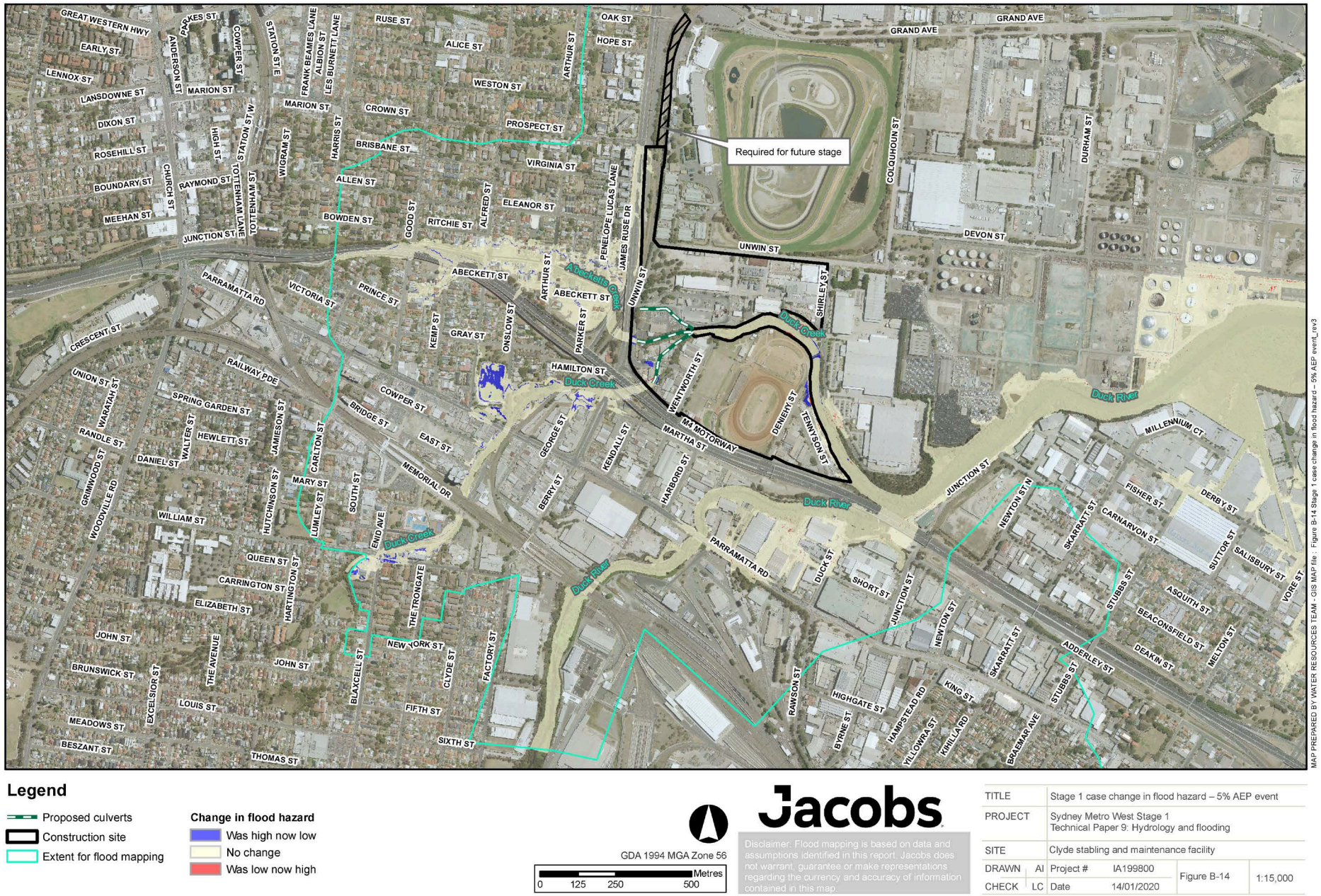


Figure B-14: Developed case change in flood hazard – 5% AEP event

Figure B-15: Developed case change in flood hazard – 1% AEP event

Legend

- Proposed culverts
- Construction site
- Extent for flood mapping

Change in flood hazard

- Was high now low
- No change
- Was low now high

GDA 1994 MGA Zone 56

0 125 250 500 Metres

Jacobs

Disclaimer: Flood mapping is based on data and assumptions identified in this report. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

TITLE		Stage 1 case change in flood hazard- Probable maximum flood			
PROJECT		Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding			
SITE		Clyde stabling and maintenance facility			
DRAWN	AI	Project #	IA199800	Figure B-16	1:15,000
CHECK	LC	Date	15/01/2020		

Figure B-16: Developed case change in flood hazard – Probable Maximum Flood event

Figure B-17: Locations of duration of inundation reporting

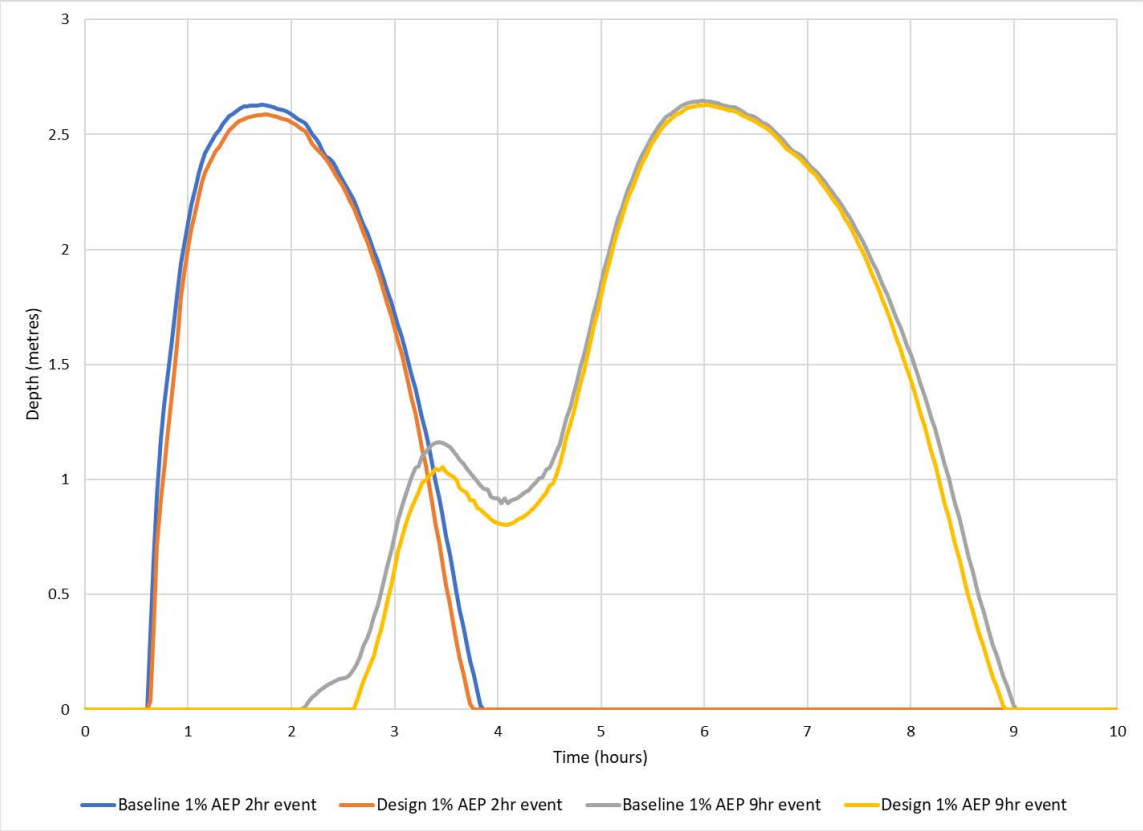


Figure B-18: Flood level versus time – 1% AEP event, A'Becketts Creek upstream of James Ruse Drive

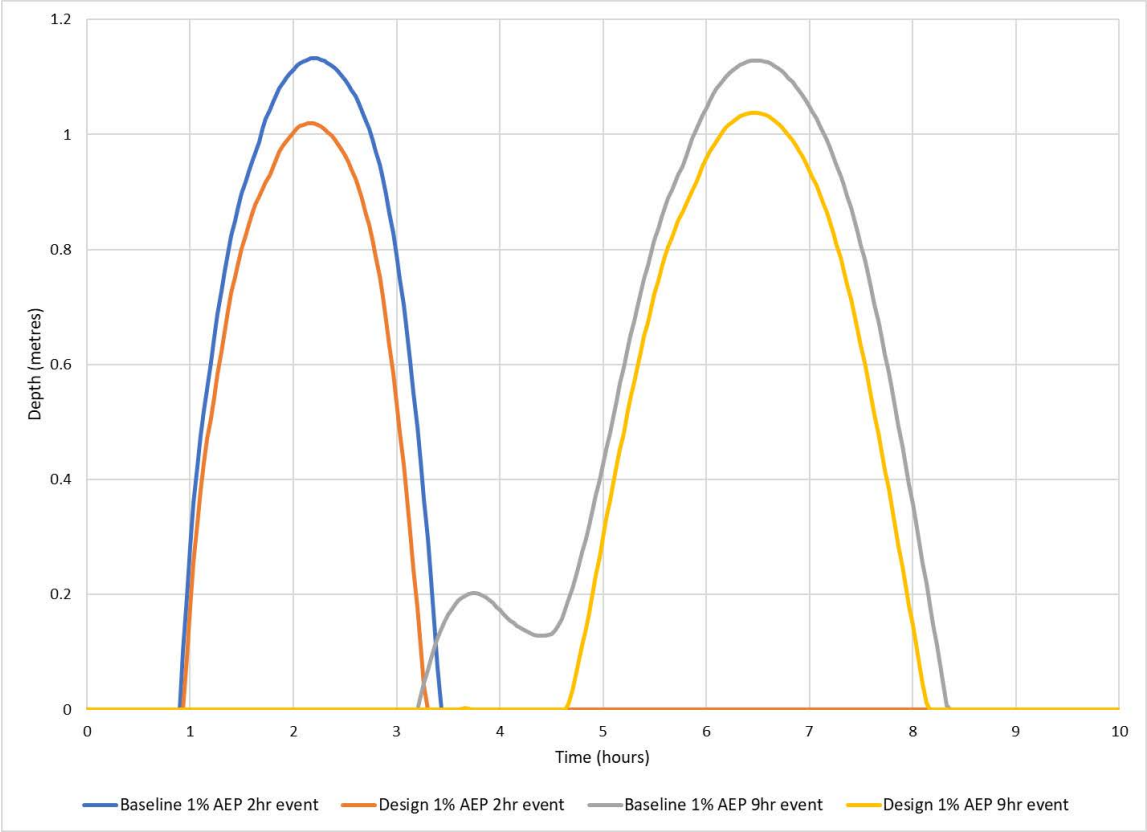


Figure B-19: Flood level versus time – 1% AEP event, Duck Creek upstream of M4 Motorway

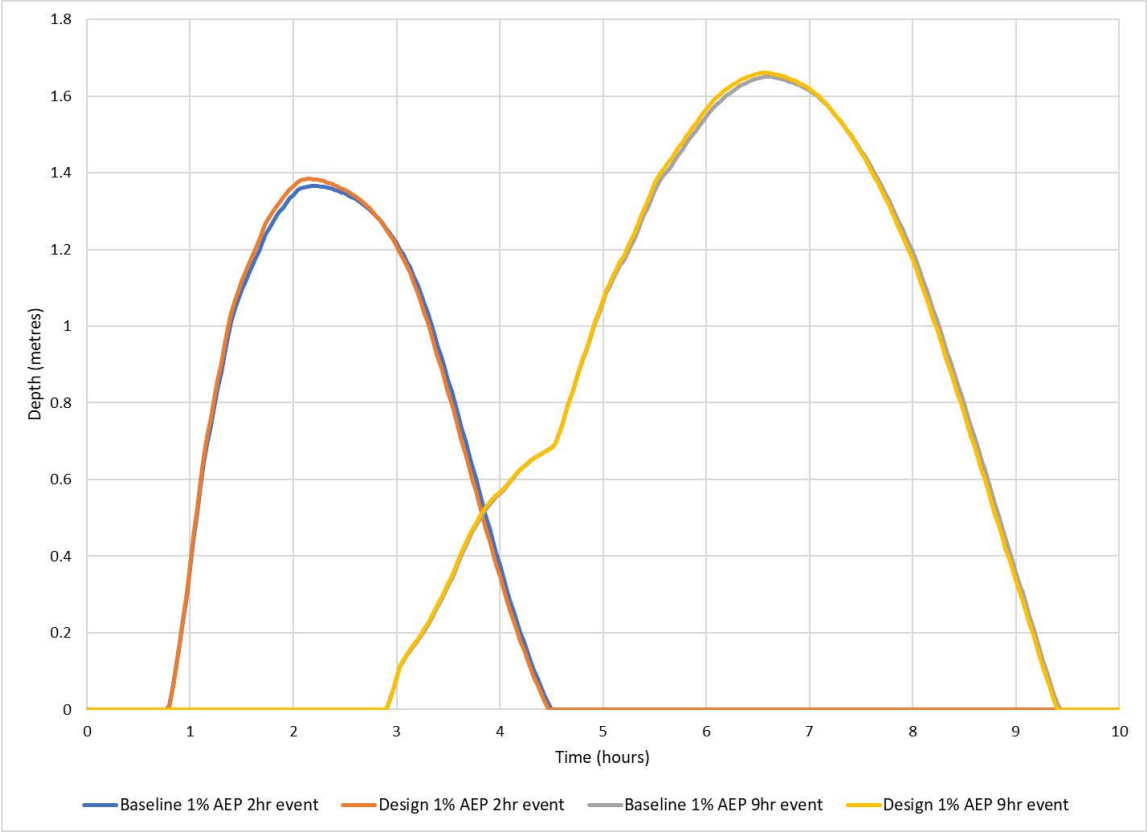


Figure B-20: Flood level versus time – 1% AEP event, Duck River upstream of M4 Motorway

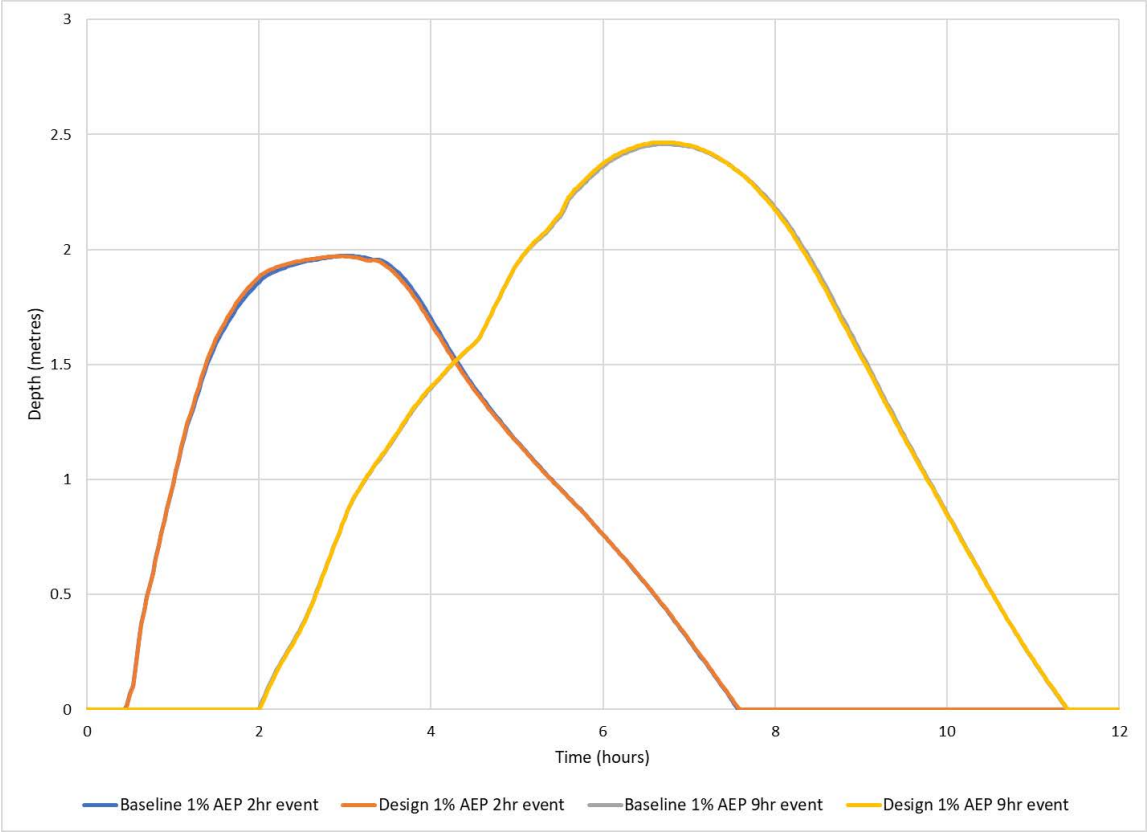
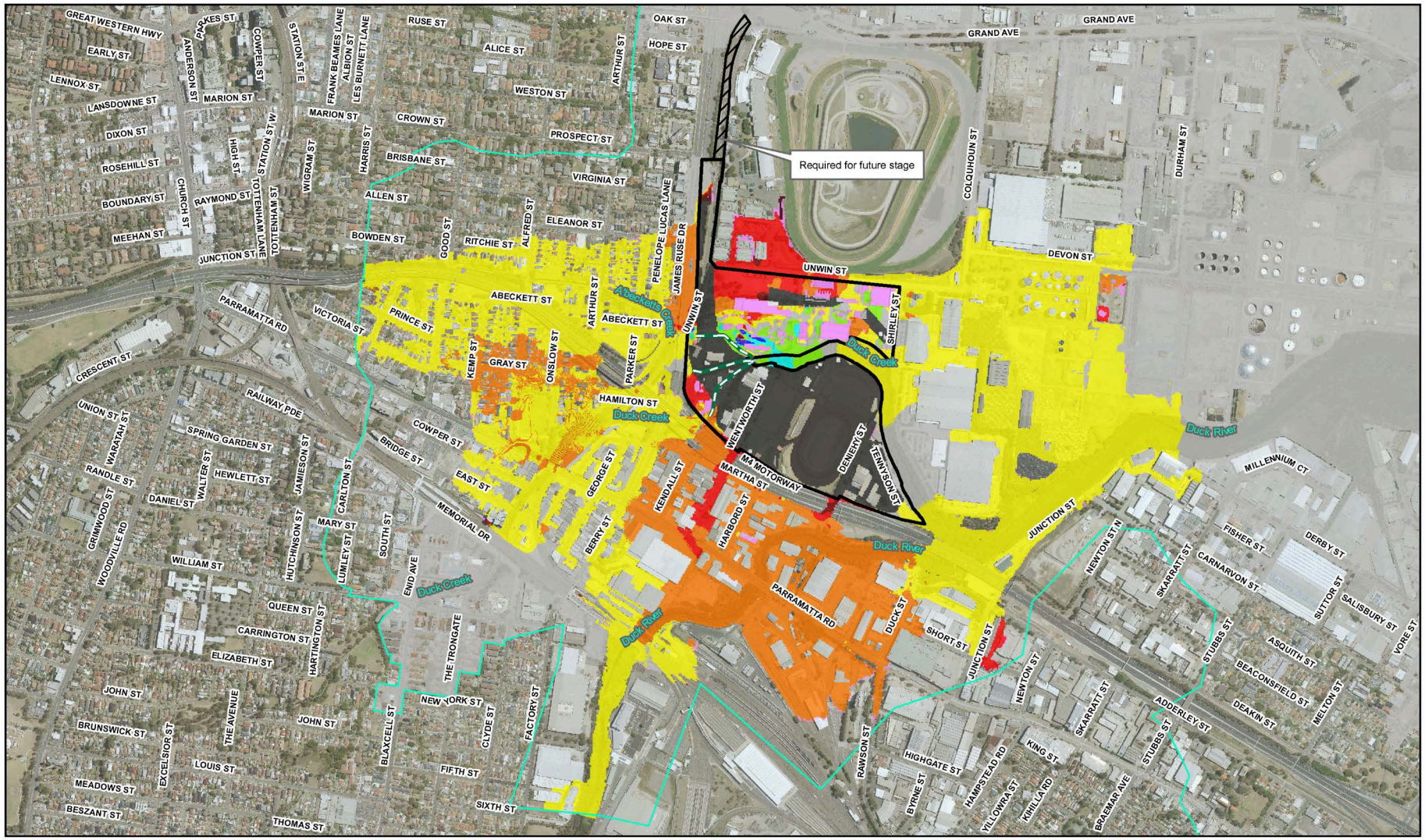


Figure B-21: Flood level versus time – 1% AEP event, Duck River near Fariola Street, Silverwater



Legend

- Construction site
- Extent for flood mapping
- Proposed culverts

Change in flood levels (metres)

- < -0.30
- -0.30 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- >0.30
- Was dry now wet
- Was wet now dry

GDA 1994 MGA Zone 56

0 125 250 500 Metres

Jacobs

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TITLE		Climate change impact assessment – Probable maximum flood event			
PROJECT		Sydney Metro West Stage 1 Technical Paper 9: Hydrology and flooding			
SITE		Clyde stabling and maintenance facility			
DRAWN	AI	Project #	IA199800	Figure B-22	1:15,000
CHECK	LC	Date	14/01/2020		

Figure B-22: Climate change impact assessment – PMF event